STEAM SUPERHEATERS

THE
BABCOCK & WILCOX

STEAM
SUPERHEATERS

THE BABCOCK & WILCOX CO.
NEW YORK

Bartlett-Orr Press
New York

THE BABCOCK & WILCOX CO.

85 LIBERTY STREET, NEW YORK, U. S. A.

Works

BAYONNE . NEW JERSEY
BARBERTON . . . OHIO

Directors

E. H. WELLS, *President*	J. E. EUSTIS, *Secretary*
W. D. HOXIE, *1st Vice-President*	F. G. BOURNE
E. R. STETTINIUS, *2nd Vice-President*	O. C. BARBER
J. G. WARD, *Treasurer*	C. A. KNIGHT

Branch Offices

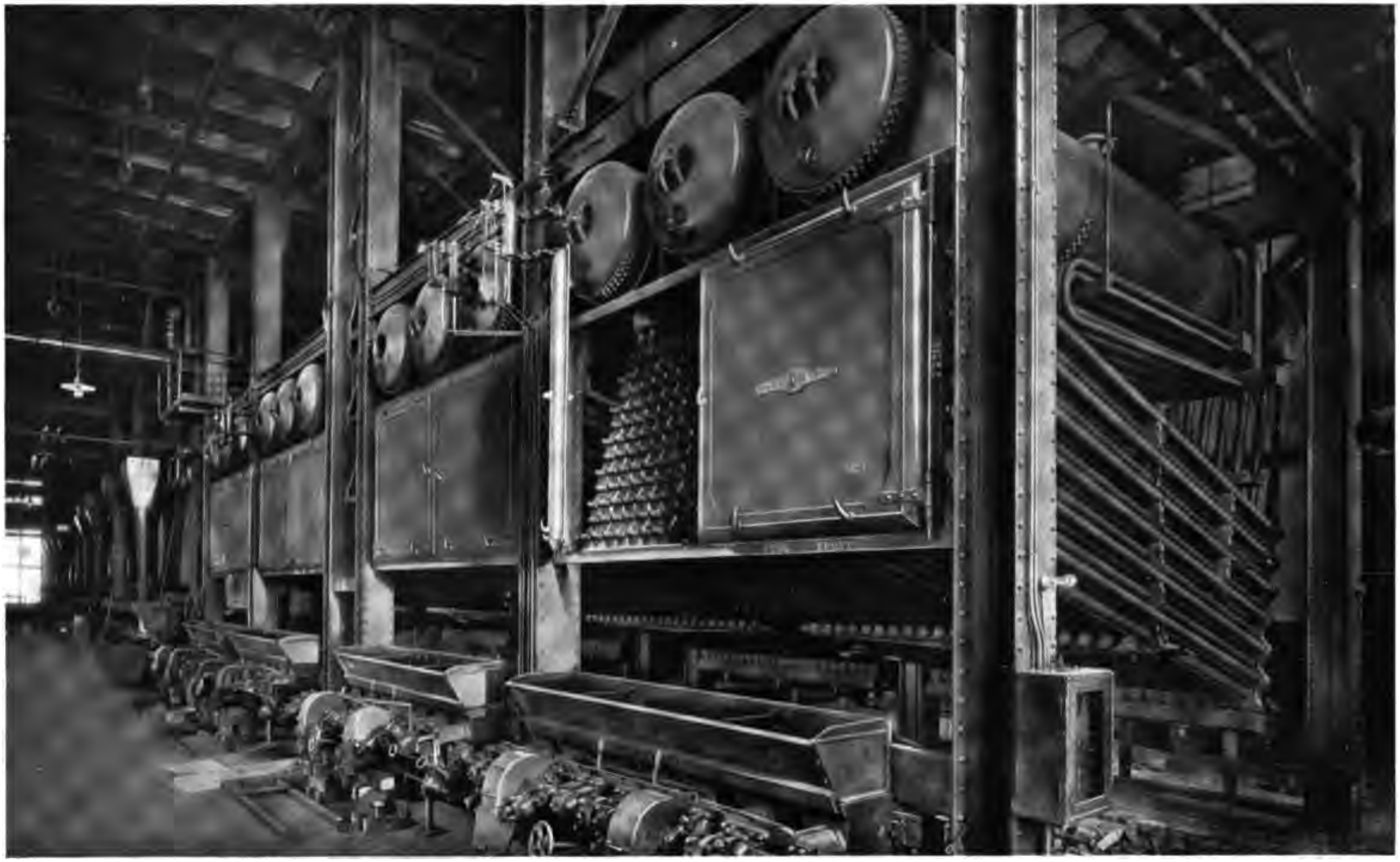
ATLANTA	CANDLER BUILDING
BOSTON	35 FEDERAL STREET
CHICAGO	MARQUETTE BUILDING
CINCINNATI	TRACTION BUILDING
CLEVELAND	NEW ENGLAND BUILDING
DENVER	435 SEVENTEENTH STREET
HAVANA, CUBA	104 CALLE DE AGUIAR
HOUSTON	SOUTHERN PACIFIC BUILDING
LOS ANGELES	I. N. VAN NUY'S BUILDING
NEW ORLEANS	SHUBERT ARCADE
PHILADELPHIA	NORTH AMERICAN BUILDING
PITTSBURGH	FARMERS' DEPOSIT BANK BUILDING
PORTLAND, ORE.	SPALDING BUILDING
SALT LAKE CITY	KEARNS BUILDING
SAN FRANCISCO	40 FIRST STREET
SEATTLE	MUTUAL LIFE BUILDING
TUCSON, ARIZ.	SANTA RITA HOTEL BUILDING

Export Department, New York: Alberto de Verastegui, Director

TELEGRAPHIC ADDRESS: FOR NEW YORK, "*GLOVEBOXES*";
FOR HAVANA, "*BABCOCK*"

WORKS OF THE BABCOCK & WILCOX CO., AT BAYONNE, NEW JERSEY

WORKS OF THE BABCOCK & WILCOX CO., AT BARBERTON, OHIO



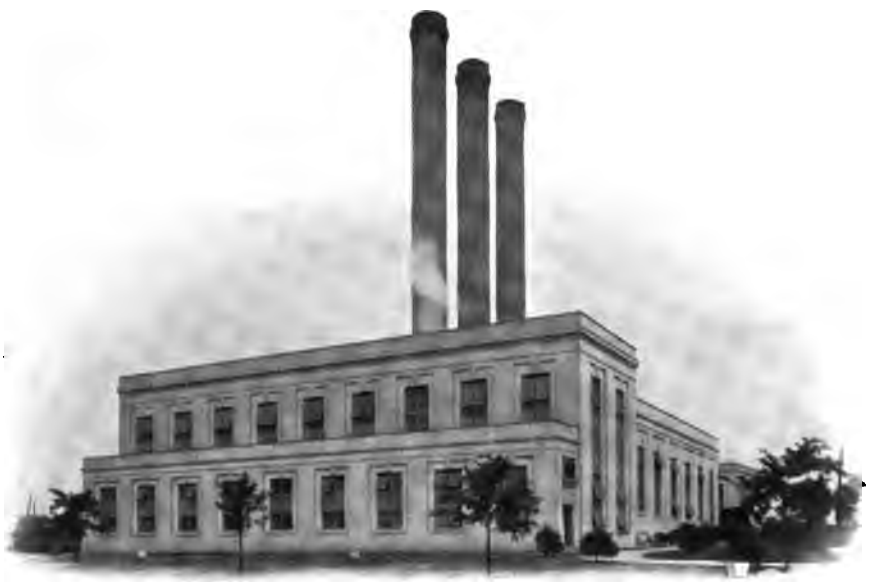
PENNSYLVANIA RAILROAD CO., LONG ISLAND CITY, N. Y., POWER STATION. 18,700 HORSE POWER OF BABCOCK & WILCOX BOILERS, EQUIPPED WITH BABCOCK & WILCOX SUPERHEATERS INSTALLED IN THIS PLANT. THIS COMPANY HAS BABCOCK & WILCOX SUPERHEATERS INSTALLED IN 31,800 HORSE POWER OF BABCOCK & WILCOX AND STIRLING BOILERS

SUPERHEATED STEAM

SATURATED steam, or water vapor, is steam at the lowest temperature at which it can exist as a vapor under a given pressure. Dry saturated steam not in contact with the water from which it has been formed may have its temperature increased above that corresponding to its existing pressure. Steam whose temperature is higher than the temperature of saturated steam at a given pressure is said to be superheated, the difference in its temperature and that of saturated steam at the same pressure being the degree of superheat. Superheating requires isolation from the liquid and saturated steam cannot be superheated while in contact with water if the water is maintained at the same temperature as the steam.

Superheated steam can and does often exist in the presence of water, but when such is the case the temperature of the water is lower than that of the superheated steam.

Superheated steam cannot condense until its temperature has been reduced to the temperature of saturated steam under the pressure at which it exists. Just so long as its temperature is above that of saturated steam at a corresponding pressure it is superheated, and before condensation can take place that amount of superheat must first be lost through radiation or other means.



COMMONWEALTH EDISON CO., CHICAGO, ILL. FISK STREET STATION. BABCOCK & WILCOX SUPERHEATERS INSTALLED IN 59,700 HORSE POWER OF BABCOCK & WILCOX BOILERS. THIS COMPANY HAS INSTALLED IN ITS VARIOUS STATIONS 101,600 HORSE POWER OF BABCOCK & WILCOX BOILERS, EQUIPPED WITH BABCOCK & WILCOX SUPERHEATERS

HISTORY OF THE USE OF SUPERHEATED STEAM

WHILE it is only within recent years that there has been any comprehensive data available on the properties of superheated steam, its use is old. Pioneers in the field of modern engineering unquestionably realized that cylinder condensation was the principal cause of low engine efficiency and many devices were tried with a view to its reduction. As early as 1705, Denys Papin, in an improved form of Dr. Savery's engine, produced what was in effect a non-condensing, single acting steam pump with the steam and water cylinders in one. He utilized a mass of heated metal placed in a recess in the diaphragm or piston, on the steam side, to reduce condensation. As the metal cooled it could be lifted from its position and replaced by another heated mass. The boiler was attached directly to the steam cylinder and Papin's device was essentially a superheater.

Probably the first practical use of superheated steam was that referred to in the "Life of Richard Trevethick." This book states that in 1828 a Captain MacGregor at a mine in Cornwall, England, spurred by the high duty record of a pumping engine whose cylinder had been insulated with sawdust, built a brick jacket about his cylinder and steam pipe, leaving a chamber between the brick and the metal, and by building a fire within this open space increased the duty of his engine some 50 per cent. Trevethick experimented with this engine and "superheater" and showed a saving in the coal used by the boiler furnishing it steam of approximately 26 per cent. There appears to be no published record of the attention that such an increase in efficiency must have aroused.

It is recorded that in 1834 John Ericsson made some experiments with superheated steam, but there are apparently no published results. Longridge, in 1845, and Rafford, in 1851, also experimented with superheated steam, but the records of both their experiments and results are meager.

For a period of twenty years after 1850 there was a marked interest on the part of engineers in superheated steam and its use. Hirn, in 1857, conducted a great number of experiments with steam at a pressure of about 35 pounds and with temperatures ranging from 410 to 490 degrees Fahrenheit. His results showed gains of from 20 to 27 per cent, due to the use of superheat.

B. F. Isherwood, Chief of the Bureau of Steam Engineering, U. S. Navy, first experimented in 1860 with Waterman's "adheater" and an experimental engine, with and without cylinder jacketing, and showed substantial gains due to the increased steam temperatures. While admitting the gain in engine efficiency due to the use of superheat, Isherwood at first was skeptical as to its practical use and declared against its advisability because of difficulties in lubrication, injury to cylinders and, with reference to marine practice, because of additional weight. During 1862-1864 he conducted an extensive series of tests on the

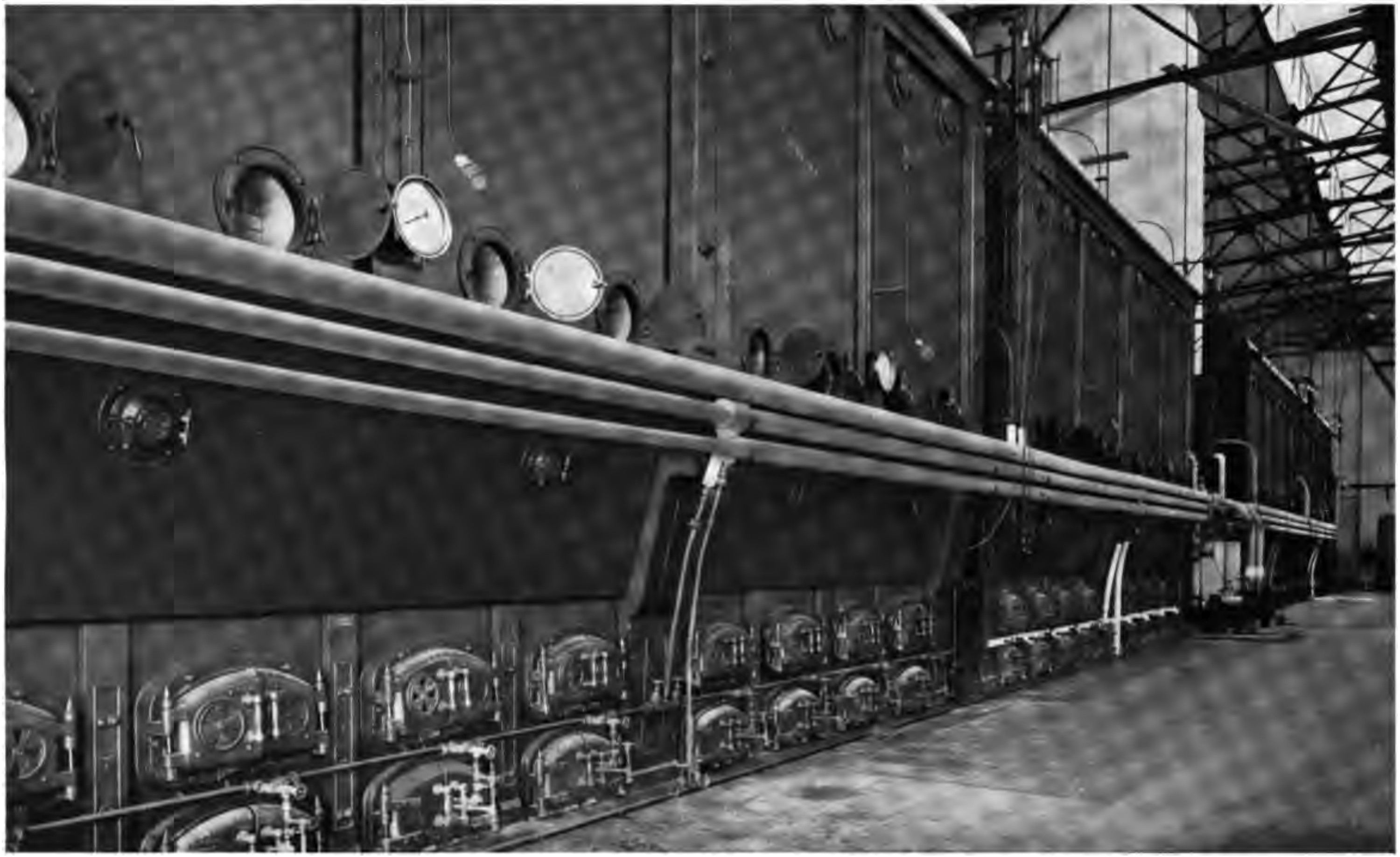
UNITED ELECTRIC LIGHT AND POWER CO., 201st STREET STATION, NEW YORK CITY. BABCOCK & WILCOX SUPERHEATERS INSTALLED IN 21,000 HORSE POWER OF BABCOCK & WILCOX BOILERS

vessels "Georgiana," "Adelaide," "Eutaw" and "Mackinaw," showing a saving due to the use of superheat as high as 30 per cent. The tests on the "Eutaw" were very carefully conducted and the gain here in steam economy was approximately 18 per cent, and in coal consumption 15 per cent. In view of these results, Isherwood ultimately recommended the use of superheaters but suggested that 100 degrees be placed as the limit of added temperature because of lubricating difficulties.

A very large proportion of the superheaters installed throughout this period were in connection with marine boilers and it may be said that during the sixties their use was general. These superheaters followed three general designs. The simplest were of cylindrical form in which the steam was made to pass through an annular space or a series of annular spaces between plates, either in or about the uptake of a boiler. Such superheaters were built in 1859 by Messrs. Dudgeon, James Watt & Co. and John Rowan & Sons. The second design was tubular, the tubes in certain types, as in the Joshua Field (1859), being flattened, horizontal tubes connecting boxes placed in the uptakes of two boilers, back to back. John Penn used a similar design, though the tubes were not flattened. By way of comparison with present-day practice, Penn's superheater had a heating surface of 2¾ square feet per nominal horse power, the boilers being rated on a basis of 19 square feet per horse power. Penn and others also used vertical tube superheaters where the products of combustion passed through the tubes and around the shell and the steam around the tubes. This construction was used with a view to easier cleaning of "the sediment from the steam which collects within the tubes." The third design of superheater was constructed of sheets and consisted of a box formed of flat plates bent to a sinuous form and placed within the boiler uptake. A number of such superheaters were placed in the Peninsular & Oriental Steam Navigation Company's steamships about 1865.

It is to be remembered that all of the boilers to which the superheaters just described were attached were operating at pressures considerably less than 50 pounds per square inch. Such being the case, 100 degrees of superheat represents an ultimate temperature of only 398 degrees. Practically all of the superheaters were located in the boiler uptakes, where the temperatures of the escaping gases were sufficiently high to heat the steam to this point. While a great deal of trouble was experienced in lubricating the cylinders of the engine, even with the temperatures below 400 degrees, still the economy of superheaters with single expansion engines was generally accepted.

As early as 1845, M'Naught had compounded, or "M'Naughted," cylinders, and Pole (1850), Elder (1854) and Cowper (1857) advanced the design of compound engines. In the late sixties compound engines had come into very general use. Their introduction was accompanied by the use of high pressure steam and these two factors combined to force the superheater temporarily out of the field. Such engines, using high pressure, showed an increase in efficiency over the single expansion engines and the low pressures that had been in vogue, greater than



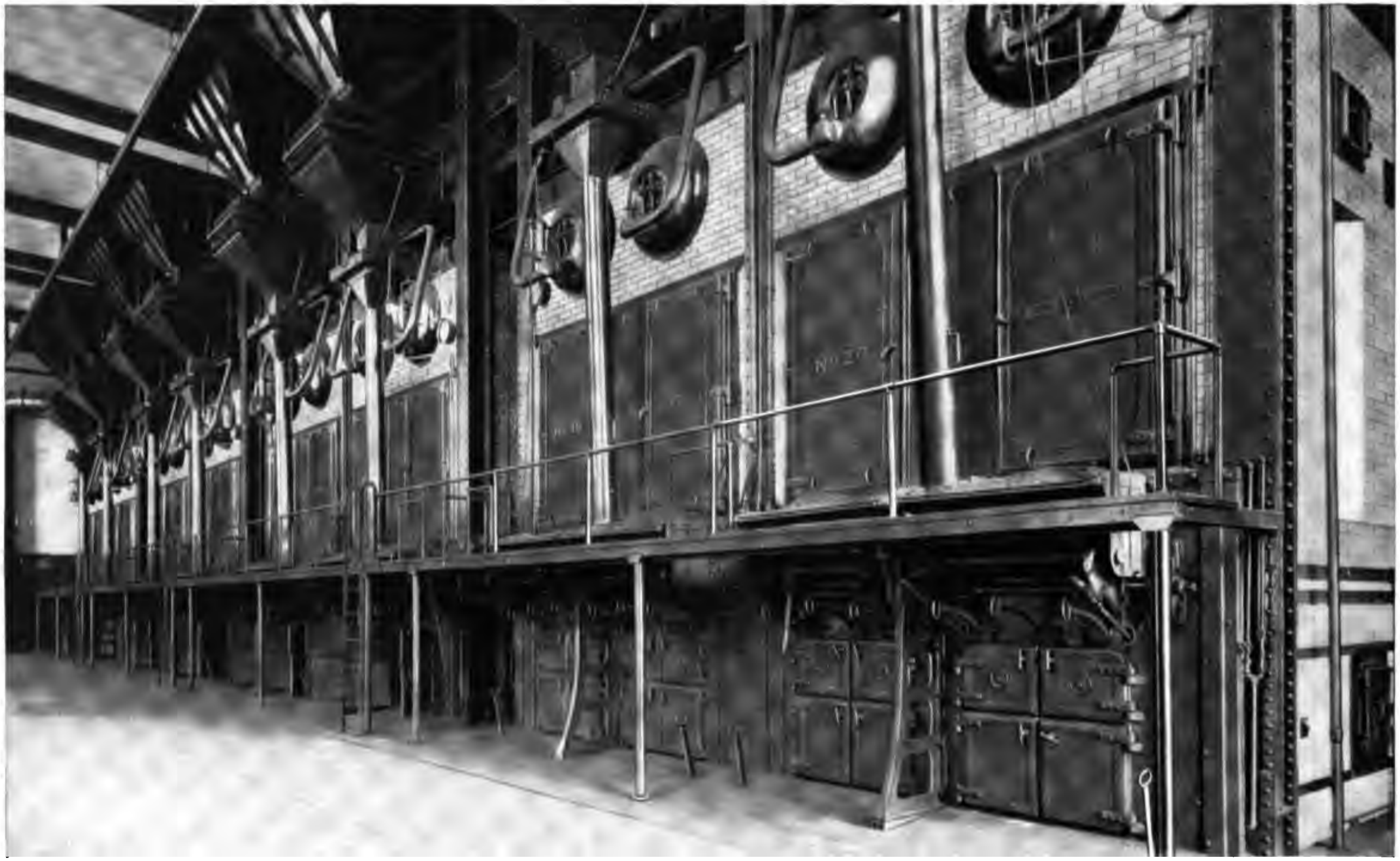
SOUTHERN CALIFORNIA EDISON CO., LONG BEACH, CAL. BABCOCK & WILCOX SUPERHEATERS INSTALLED IN 6200 HORSE POWER OF STIRLING BOILERS

that obtained simply by the use of superheated low pressure steam. With the increase in the pressure there was an increase in the temperature and where attempts were made to superheat the high pressure steam to the same degree as had been the practice with the low pressure steam, great difficulty was experienced in lubrication, the present mineral cylinder oils being then unknown, and in some cases the designs being unsuitable for superheated steam. Where superheaters were used it was found necessary to reduce the amount of superheat to a point where its gain was too small to warrant the expense of a superheater installation. The almost universal use of compound engines in marine practice thus made the adoption of superheaters impracticable. Although superheaters had never been as extensively used in stationary work, they were abandoned on land at the same time as at sea. Dr. Kirk introduced the triple expansion engine in 1874 and by 1881 it had become the normal type of marine engine, and the still further increase in steam pressure for this type of engine was an additional factor militating against the use of superheaters.

It is interesting to note that the British Board of Trade took a strong stand against the use of superheated steam on the ground that there was danger of the steam being broken into its constituent elements at high temperatures, and becoming dangerous. This stand, while wholly in error, had an effect in retarding development.

The use of mineral oils became general in the early seventies (though our present day heavy cylinder oils were unknown) and its use might have furnished the solution of the lubrication difficulties arising from the use of superheated steam had it not been for the fact that the foremost engineers were devoting their whole attention to the increase in efficiency of engines from the use of higher pressures, compounding, and improvements in mechanical details of valve gears, governors, and the like. Superheated steam through this period seems to have been almost entirely forgotten or discarded because of bad reports. A. E. Seaton, in "A Manual of Marine Engineering" (1883), says: "The use of superheated steam has been discontinued since the pressure has gone beyond 60 pounds per square inch, partly in consequence of the increase in temperature beyond that due to the pressure being prejudicial to the good working of certain parts, partly also due to the danger and inconvenience of the superheater itself, and not a little to the action taken by the Board of Trade (British) with respect to it." This statement was made in editions of Seaton's manual as late as 1890.

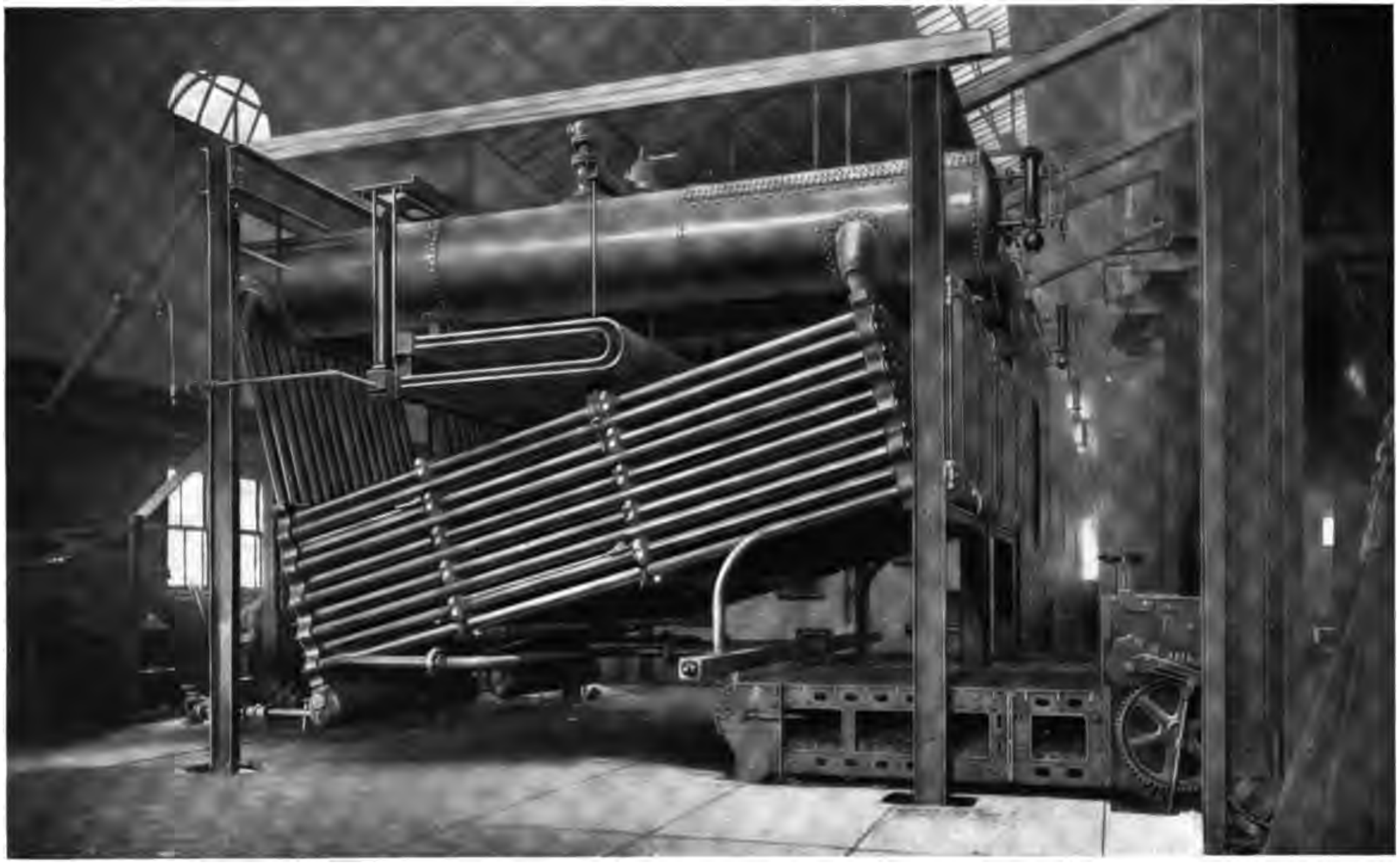
There were certain engineers who continued to investigate and experiment with superheated steam through the period when the general interest in the subject was apparently lost. Hirn, his successor, Schwoerer, Schröter, and William Schmidt were pioneers in this second movement toward the introduction of superheated steam. Hirn, in 1892, acting for the Alsatian Society of Steam Users, in an extended series of tests on a large number of engines, showed a saving in coal of 20 per cent for superheaters installed integral with a boiler and 12 per cent where the superheaters were independently fired. He used steam



EDISON ELECTRIC ILLUMINATING CO., OF BOSTON, MASS. "L" STREET STATION. BABCOCK & WILCOX SUPERHEATERS INSTALLED IN 29,000 HORSE POWER OF BABCOCK & WILCOX BOILERS. THIS COMPANY OPERATES IN ITS VARIOUS STATIONS 39,000 HORSE POWER OF BABCOCK & WILCOX BOILERS AND SUPERHEATERS

superheated to from 86 to 113 degrees Fahrenheit (30 to 45 degrees centigrade). Professor Schröter, in 1895, conducted a series of tests on a boiler and engine especially designed and built for use with superheated steam by William Schmidt. This engine, utilizing steam at 156 pounds pressure, superheated to 235 degrees, while developing approximately 75 horse power showed a steam consumption of 10.4 pounds per indicated horse power or approximately 1.3 pounds of coal per indicated horse power. The published results of these tests aroused considerable interest through Europe and a number of Schmidt superheaters and engines were installed. Interest in the whole subject of the use of superheated steam revived, particularly in Europe, and a number of designs of superheaters, both integral and separately fired, were brought out. Babcock & Wilcox, Limited, built its first superheaters in 1895 and their success was immediate.

The Babcock & Wilcox Co. began building superheaters in 1898 and this company was the first to commercially market apparatus of this type in this country.



CITY OF CLEVELAND, OHIO, WATER WORKS. BABCOCK & WILCOX BOILER AND SUPERHEATER IN COURSE OF ERECTION
BABCOCK & WILCOX SUPERHEATERS INSTALLED IN 2300 HORSE POWER OF BABCOCK & WILCOX
BOILERS IN THIS PLANT

PROPERTIES OF SUPERHEATED STEAM

WHILE, as has been seen, the use of superheated steam is old, but little was known until recently of its properties.

In the preparation and computation of a table giving the properties of superheated steam the important factor is its specific heat. Without this value it is impossible to determine the total heat of superheated steam, that is, the amount of heat that must be applied to bring saturated steam to any given superheated condition.

Regnault, in 1862, determined the specific heat of superheated steam, basing his value, which he gives as 0.48, upon four series of experiments, all of which covered approximately the same temperature range and all at atmospheric pressure. While Regnault's experiments in no way proved that the value of specific heat as given by him was independent of either pressure or temperature, this value was accepted for some forty years and applied to higher pressures and temperatures as well as to those within the range of his experiments.

With the revival of the use of superheated steam in the nineties, the assumption that the specific heat was constant regardless of pressure and temperature was found to be incorrect and a number of investigators turned their attention to the subject. Grindley and Greissmann's experiments, in 1900, appeared to indicate that the specific heat increased with the temperature and was independent of the pressure. Other investigators, however, proved this untrue. Among those giving their services in this investigation were Lorenz, Linde, Holborn and Henning, Callender, Carpenter, Thomas and Knoblauch and Jacob. The experiments of the last two investigators were probably the most laborious and comprehensive and they made special efforts to eliminate the presence of moisture in the steam in observations near the saturation point, an error which unavoidably crept into other investigations.

Table 1* gives, in condensed form, the properties of superheated steam as calculated by Lionel S. Marks and Harvey N. Davis. The values as given by these authorities are considered reliable and are generally accepted in engineering practice.

In determining the mean specific heat of superheated steam for various temperatures and pressures and from these values the total heat, Messrs. Marks and Davis use the values as determined by Knoblauch and Jacob, modifying their C_p (or specific heat at constant pressure) curves in two respects; the first consists in modifications of the C_p curves at low pressures near the point of saturation because of thermodynamic evidence and because of Regnault's experiments at atmospheric pressure; the second modification is in the C_p curves for high degrees of superheat to follow Holborn and Henning's curve, which they consider authentic.

* See pages 25 to 27.

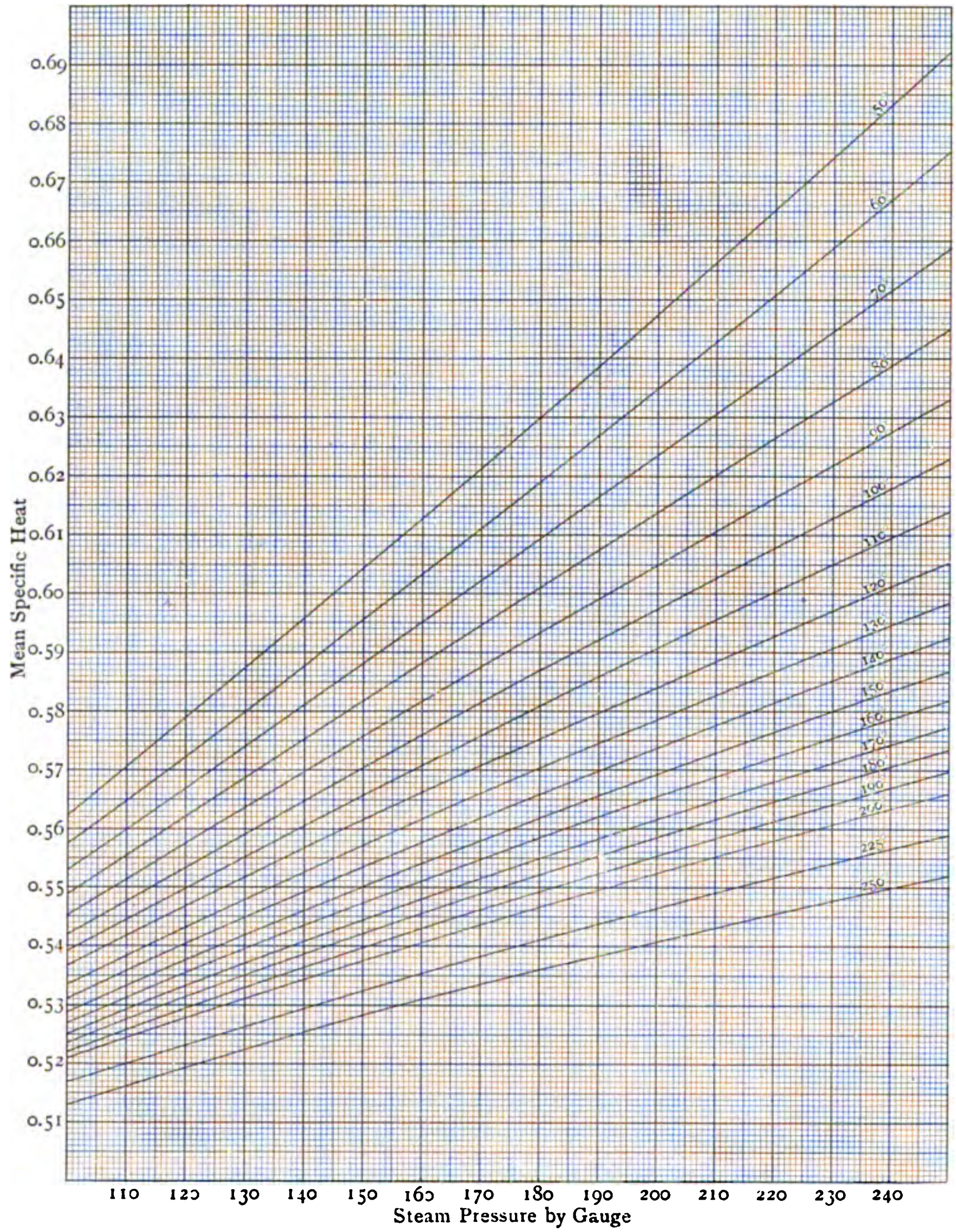


FIG. 1. MEAN SPECIFIC HEAT OF SUPERHEATED STEAM

Calculated from Marks and Davis

CURVES REPRESENT DEGREES OF SUPERHEAT

The values given for total heat at various temperatures may be represented by:

$$H = h + r + C_p\,(T_{sup.} - T_{sat.})$$

Where h=heat of liquid at existing pressure,

r=latent heat of evaporation of saturated steam at this pressure,

C_p=mean specific heat at existing pressure and ultimate temperature,

$T_{sup.}$ and $T_{sat.}$=temperatures of superheated and of saturated steam.

The mean specific heat must be distinguished from the actual specific heat at any temperature and pressure. The actual specific heat at a given pressure and temperature is that corresponding to a change in temperature of one degree, while the mean specific heat is the average for all temperatures from that of saturated steam up to the ultimate temperature of the superheated steam at the existing pressure.

The temperatures given in the table are the ultimate temperatures of the superheated steam, the degree of superheat being represented by these ultimate temperatures less that of saturated steam at a corresponding pressure.

The specific volumes are based on values as given by Knoblauch, Linde and Klebe. Of all the corrective characteristic equations for superheated steam, that advanced by these authorities is probably the most satisfactory. This is:

$$pv = BT - p\,(1 + ap)\left(C\left\{\frac{373}{T}\right\}^3 - D\right)$$

Where p=pressures in kilograms per square meter,

v=volume in cubic meters,

T=absolute temperatures degrees centigrade,

a, B, C and D=constants.

Reduced to English units, the pressures being in pounds per square inch, the volume in cubic feet per pound and the temperature in degrees Fahrenheit this becomes:

$$pv = 0.5962\ T - p\,(1 + 0.0014\,p)\left(\frac{150,300,000}{T^3} - 0.0833\right)$$

In engineering work it is frequently necessary to know the mean specific heat of superheated steam at a given pressure and temperature. Fig. 1 shows graphically values of this mean specific heat for various temperatures and pressures and has been computed from values of total heat as given in Marks and Davis' steam tables. The calculation involved, expressed as a formula, is:

$$\text{Sp. Ht.} = \frac{H - h}{T_{sup.} - T_{sat.}}$$

Where Sp. Ht.=mean specific heat at a given pressure and temperature,

H=total heat of superheated steam at a given temperature and pressure,

h=total heat of saturated steam at the corresponding pressure,

$T_{sup.}$ and $T_{sat.}$=temperatures of superheated and saturated steam.

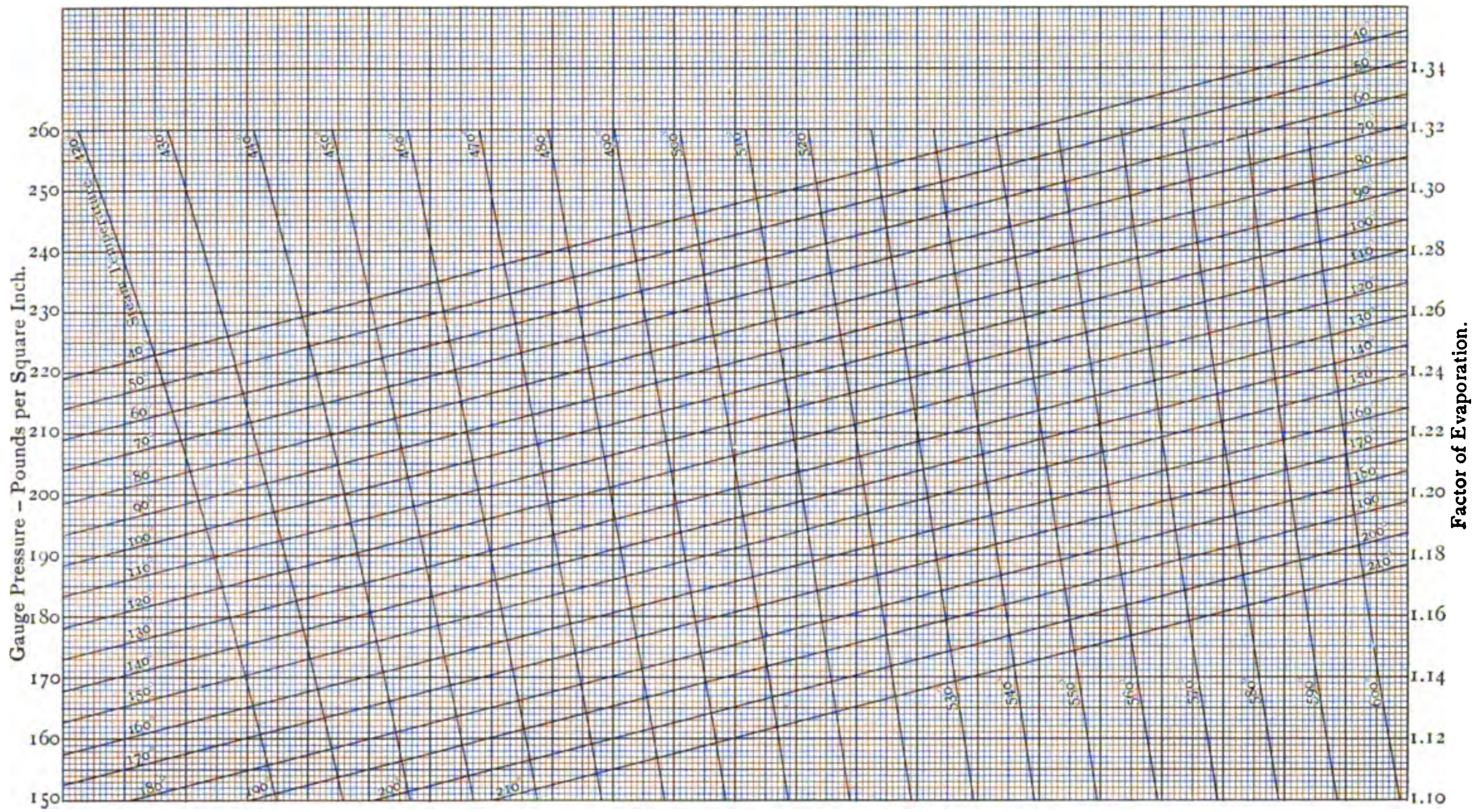


FIG. 2. FACTORS OF EVAPORATION WITH SUPERHEATED STEAM

Calculated from Marks and Davis

TRANSVERSE LINES REPRESENT TEMPERATURE OF FEED WATER

Factor of Evaporation with Superheated Steam — When superheat is present in steam during a boiler trial and superheated steam tables are available, the method of calculating the factor of evaporation is the same as in the case of saturated steam, namely:

$$\text{Factor} = \frac{H - q}{L}$$

Where H = total heat in superheated steam,

q = sensible heat in the feed water above 32 degrees Fahrenheit,

L = 970.4, the latent heat of evaporation at atmospheric pressure.

If no superheated steam tables are available but values of the specific heat of superheated steam are at hand, this formula may be expressed:

$$\text{Factor} = \frac{H' - q + C_p\,(T_{sup.} - T_{sat.})}{L}$$

Where H′ = total heat in the saturated steam at the pressure found in the trial,

q = sensible heat in the feed water above 32 degrees Fahrenheit.

C_p = the mean specific heat of superheated steam at temperature and pressure existing in the trial,

$T_{sup.}$ and $T_{sat.}$ = temperatures of superheated and saturated steam.

For approximate work a chart may be used for determining factors of evaporation with superheated steam. Fig. 2 shows a graphic method of making such determination, the chart being used as follows: From the gauge pressure existing in the boiler trial, as shown by the scale on the left, proceed on a horizontal line to the intersection with the curve of ultimate steam temperature. From this intersection proceed vertically to the line of feed water temperature, and from this latter point horizontally to the scale of factors at the right.

COMMONWEALTH EDISON CO., CHICAGO, ILL. NORTHWEST STATION. BABCOCK & WILCOX SUPERHEATERS INSTALLED IN 17,400 HORSE POWER OF BABCOCK & WILCOX BOILERS IN THIS STATION

TABLE 1

PROPERTIES OF SUPERHEATED STEAM

REPRODUCED BY PERMISSION FROM MARKS AND DAVIS "STEAM TABLES AND DIAGRAMS"

Pressure Pounds Absolute		Saturated Steam	Degrees of Superheat 50	100	150	200	250	300		Pressure Pounds Absolute
	t	162.3	212.3	262.3	312.3	362.3	412.3	462.3	t	
5	v	73.3	79.7	85.7	91.8	97.8	103.8	109.8	v	5
	h	1130.5	1153.5	1176.4	1199.5	1222.5	1245.6	1268.7	h	
	t	193.2	243.2	293.2	343.2	393.2	443.2	493.2	t	
10	v	38.4	41.5	44.6	47.7	50.7	53.7	56.7	v	10
	h	1143.1	1166.3	1189.5	1212.7	1236.0	1259.3	1282.5	h	
	t	213.0	263.0	313.0	363.0	413.0	463.0	513.0	t	
15	v	26.27	28.40	30.46	32.50	34.53	36.56	38.58	v	15
	h	1150.7	1174.2	1197.6	1221.0	1244.4	1267.7	1291.1	h	
	t	228.0	278.0	328.0	378.0	428.0	478.0	528.0	t	
20	v	20.08	21.69	23.25	24.80	26.33	27.85	29.37	v	20
	h	1156.2	1179.9	1203.5	1227.1	1250.6	1274.1	1297.6	h	
	t	240.1	290.1	340.1	390.1	440.1	490.1	540.1	t	
25	v	16.30	17.60	18.86	20.10	21.32	22.55	23.77	v	25
	h	1160.4	1184.4	1208.2	1231.9	1255.6	1279.2	1302.8	h	
	t	250.4	300.4	350.4	400.4	450.4	500.4	550.4	t	
30	v	13.74	14.83	15.89	16.93	17.97	18.99	20.00	v	30
	h	1163.9	1188.1	1212.1	1236.0	1259.7	1283.4	1307.1	h	
	t	259.3	309.3	359.3	409.3	459.3	509.3	559.3	t	
35	v	11.89	12.85	13.75	14.65	15.54	16.42	17.30	v	35
	h	1166.8	1191.3	1215.4	1239.4	1263.3	1287.1	1310.8	h	
	t	267.3	317.3	367.3	417.3	467.3	517.3	567.30	t	
40	v	10.49	11.33	12.13	12.93	13.70	14.48	15.25	v	40
	h	1169.4	1194.0	1218.4	1242.4	1266.4	1290.3	1314.1	h	
	t	274.5	324.5	374.5	424.5	474.5	524.5	574.5	t	
45	v	9.39	10.14	10.86	11.57	12.27	12.96	13.65	v	45
	h	1171.6	1196.6	1221.0	1245.2	1269.3	1293.2	1317.0	h	
	t	281.0	331.0	381.0	431.0	481.0	531.0	581.0	t	
50	v	8.51	9.19	9.84	10.48	11.11	11.74	12.36	v	50
	h	1173.6	1198.8	1223.4	1247.7	1271.8	1295.8	1319.7	h	
	t	287.1	337.1	387.1	437.1	487.1	537.1	587.1	t	
55	v	7.78	8.40	9.00	9.59	10.16	10.73	11.30	v	55
	h	1175.4	1200.8	1225.6	1250.0	1274.2	1298.1	1322.0	h	
	t	292.7	342.7	392.7	442.7	492.7	542.7	592.7	t	
60	v	7.17	7.75	8.30	8.84	9.36	9.89	10.41	v	60
	h	1177.0	1202.6	1227.6	1252.1	1276.4	1300.4	1324.3	h	
	t	298.0	348.0	398.0	448.0	498.0	548.0	598.0	t	
65	v	6.65	7.20	7.70	8.20	8.69	9.17	9.65	v	65
	h	1178.5	1204.4	1229.5	1254.0	1278.4	1302.4	1326.4	h	
	t	302.9	352.9	402.9	452.9	502.9	552.9	602.9	t	
70	v	6.20	6.71	7.18	7.65	8.11	8.56	9.01	v	70
	h	1179.8	1205.9	1231.2	1255.8	1280.2	1304.3	1328.3	h	
	t	307.6	357.6	407.6	457.6	507.6	557.6	607.6	t	
75	v	5.81	6.28	6.73	7.17	7.60	8.02	8.44	v	75
	h	1181.1	1207.5	1232.8	1257.5	1282.0	1306.1	1330.1	h	
	t	312.0	362.0	412.0	462.0	512.0	562.0	612.0	t	
80	v	5.47	5.92	6.34	6.75	7.17	7.56	7.95	v	80
	h	1182.3	1208.8	1234.3	1259.0	1283.6	1307.8	1331.9	h	
	t	316.3	366.3	416.3	466.3	516.3	566.3	616.3	t	
85	v	5.16	5.59	5.99	6.38	6.76	7.14	7.51	v	85
	h	1183.4	1210.2	1235.8	1260.6	1285.2	1309.4	1333.5	h	

t = Temperature, degrees Fahrenheit.

v = Specific volume, in cubic feet, per pound.

h = Total heat from water at 32 degrees, B. t. u.

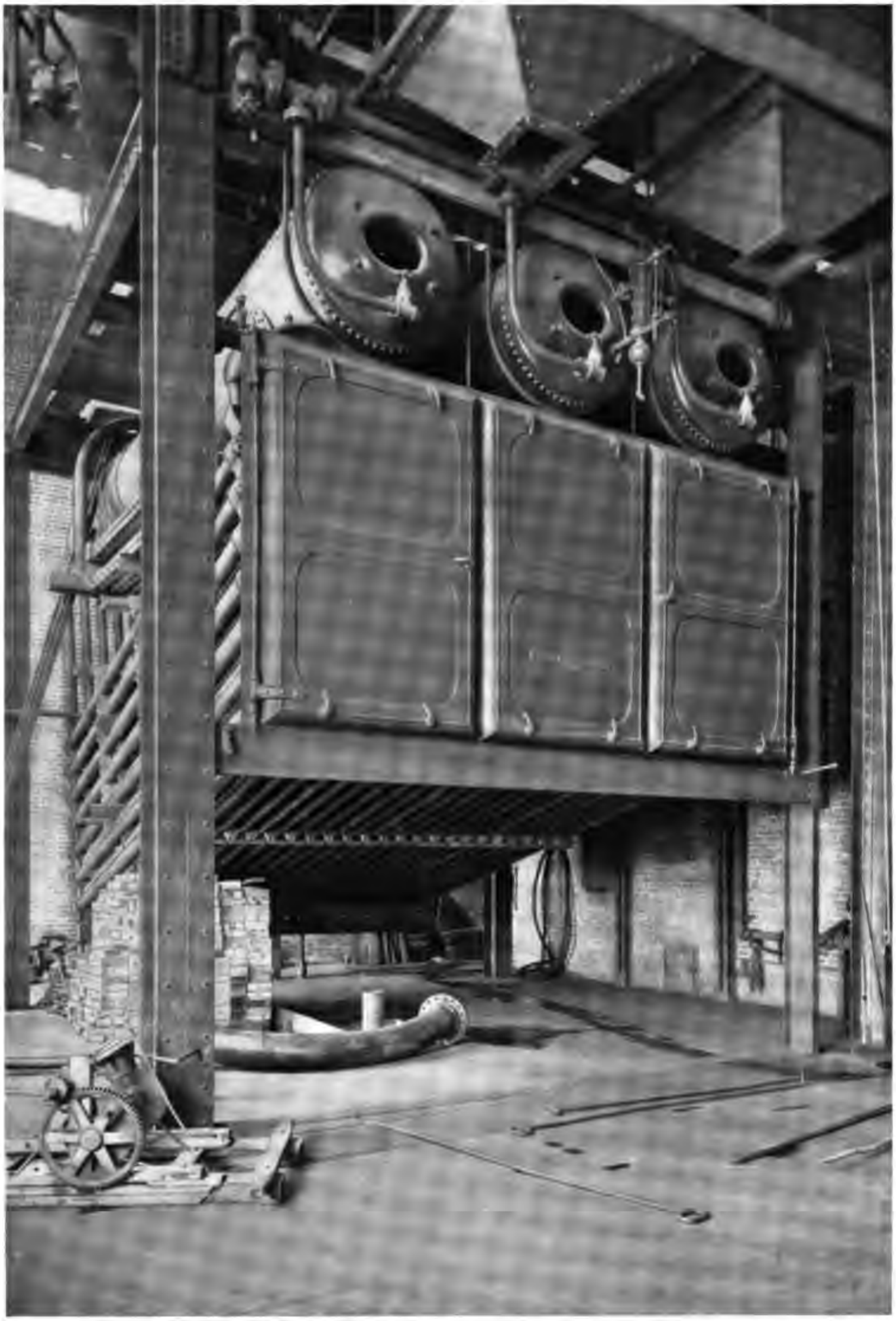
PROPERTIES OF SUPERHEATED STEAM—Continued

Pressure Pounds Absolute		Saturated Steam	Degrees of Superheat 50	100	150	200	250	300		Pressure Pounds Absolute
90	t	320.3	370.3	420.3	470.3	520.3	570.3	620.3	t	90
	v	4.89	5.29	5.67	6.04	6.40	6.76	7.11	v	
	h	1184.4	1211.4	1237.2	1262.0	1286.6	1310.8	1334.9	h	
95	t	324.1	374.1	424.1	474.1	524.1	574.1	624.1	t	95
	v	4.65	5.03	5.39	5.74	6.09	6.43	6.76	v	
	h	1185.4	1212.6	1238.4	1263.4	1288.1	1312.3	1336.4	h	
100	t	327.8	377.8	427.8	477.8	527.8	577.8	627.8	t	100
	v	4.43	4.79	5.14	5.47	5.80	6.12	6.44	v	
	h	1186.3	1213.8	1239.7	1264.7	1289.4	1313.6	1337.8	h	
105	t	331.4	381.4	431.4	481.4	531.4	581.4	631.4	t	105
	v	4.23	4.58	4.91	5.23	5.54	5.85	6.15	v	
	h	1187.2	1214.9	1240.8	1265.9	1290.6	1314.9	1339.1	h	
110	t	334.8	384.8	434.8	484.8	534.8	584.8	634.8	t	110
	v	4.05	4.38	4.70	5.01	5.31	5.61	5.90	v	
	h	1188.0	1215.9	1242.0	1267.1	1291.9	1316.2	1340.4	h	
115	t	338.1	388.1	438.1	488.1	538.1	588.1	638.1	t	115
	v	3.88	4.20	4.51	4.81	5.09	5.38	5.66	v	
	h	1188.8	1216.9	1243.1	1268.2	1293.0	1317.3	1341.5	h	
120	t	341.3	391.3	441.3	491.3	541.3	591.3	641.3	t	120
	v	3.73	4.04	4.33	4.62	4.89	5.17	5.44	v	
	h	1189.6	1217.9	1244.1	1269.3	1294.1	1318.4	1342.7	h	
125	t	344.4	394.4	444.4	494.4	544.4	594.4	644.4	t	125
	v	3.58	3.88	4.17	4.45	4.71	4.97	5.23	v	
	h	1190.3	1218.8	1245.1	1270.4	1295.2	1319.5	1343.8	h	
130	t	347.4	397.4	447.4	497.4	547.4	597.4	647.4	t	130
	v	3.45	3.74	4.02	4.28	4.54	4.80	5.05	v	
	h	1191.0	1219.7	1246.1	1271.4	1296.2	1320.6	1344.9	h	
135	t	350.3	400.3	450.3	500.3	550.3	600.3	650.3	t	135
	v	3.33	3.61	3.88	4.14	4.38	4.63	4.87	v	
	h	1191.6	1220.6	1247.0	1272.3	1297.2	1321.6	1345.9	h	
140	t	353.1	403.1	453.1	503.1	553.1	603.1	653.1	t	140
	v	3.22	3.49	3.75	4.00	4.24	4.48	4.71	v	
	h	1192.2	1221.4	1248.0	1273.3	1298.2	1322.6	1346.9	h	
145	t	355.8	405.8	455.8	505.8	555.8	605.8	655.8	t	145
	v	3.12	3.38	3.63	3.87	4.10	4.33	4.56	v	
	h	1192.8	1222.2	1248.8	1274.2	1299.1	1323.6	1347.9	h	
150	t	358.5	408.5	458.5	508.5	558.5	608.5	658.5	t	150
	v	3.01	3.27	3.51	3.75	3.97	4.19	4.41	v	
	h	1193.4	1223.0	1249.6	1275.1	1300.0	1324.5	1348.8	h	
155	t	361.0	411.0	461.0	511.0	561.0	611.0	661.0	t	155
	v	2.92	3.17	3.41	3.63	3.85	4.06	4.28	v	
	h	1194.0	1223.6	1250.5	1276.0	1300.8	1325.3	1349.7	h	
160	t	363.6	413.6	463.6	513.6	563.6	613.6	663.6	t	160
	v	2.83	3.07	3.30	3.53	3.74	3.95	4.15	v	
	h	1194.5	1224.5	1251.3	1276.8	1301.7	1326.2	1350.6	h	
165	t	366.0	416.0	466.0	516.0	566.0	616.0	666.0	t	165
	v	2.75	2.99	3.21	3.43	3.64	3.84	4.04	v	
	h	1195.0	1225.2	1252.0	1277.6	1302.5	1327.1	1351.5	h	
170	t	368.5	418.5	468.5	518.5	568.5	618.5	668.5	t	170
	v	2.68	2.91	3.12	3.34	3.54	3.73	3.92	v	
	h	1195.4	1225.9	1252.8	1278.4	1303.3	1327.9	1352.3	h	

t = Temperature, degrees Fahrenheit.
v = Specific volume, in cubic feet, per pound.
h = Total heat from water at 32 degrees, B. t. u.

Pressure Pounds Absolute		Saturated Steam	Degrees of Superheat 50	100	150	200	250	300		Pressure Pounds Absolute
	t	370.8	420.8	470.8	520.8	570.8	620.8	670.8	t	
175	v	2.60	2.83	3.04	3.24	3.44	3.63	3.82	v	175
	h	1195.9	1226.6	1253.6	1279.1	1304.1	1328.7	1353.2	h	
	t	373.1	423.1	473.1	523.1	573.1	623.1	673.1	t	
180	v	2.53	2.75	2.96	3.16	3.35	3.54	3.72	v	180
	h	1196.4	1227.2	1254.3	1279.9	1304.8	1329.5	1353.9	h	
	t	375.4	425.4	475.4	525.4	575.4	625.4	675.4	t	
185	v	2.47	2.68	2.89	3.08	3.27	3.45	3.63	v	185
	h	1196.8	1227.9	1255.0	1280.6	1305.6	1330.2	1354.7	h	
	t	377.6	427.6	477.6	527.6	577.6	627.6	677.6	t	
190	v	2.41	2.62	2.81	3.00	3.19	3.37	3.55	v	190
	h	1197.3	1228.6	1255.7	1281.3	1306.3	1330.9	1355.5	h	
	t	379.8	429.8	479.8	529.8	579.8	629.8	679.8	t	
195	v	2.35	2.55	2.75	2.93	3.11	3.29	3.46	v	195
	h	1197.7	1229.2	1256.4	1282.0	1307.0	1331.6	1356.2	h	
	t	381.9	431.9	481.9	531.9	581.9	631.9	681.9	t	
200	v	2.29	2.49	2.68	2.86	3.04	3.21	3.38	v	200
	h	1198.1	1229.8	1257.1	1282.6	1307.7	1332.4	1357.0	h	
	t	384.0	434.0	484.0	534.0	584.0	634.0	684.0	t	
205	v	2.24	2.44	2.62	2.80	2.97	3.14	3.30	v	205
	h	1198.5	1230.4	1257.7	1283.3	1308.3	1333.0	1357.7	h	
	t	386.0	436.0	486.0	536.0	586.0	636.0	686.0	t	
210	v	2.19	2.38	2.56	2.74	2.91	3.07	3.23	v	210
	h	1198.8	1231.0	1258.4	1284.0	1309.0	1333.7	1358.4	h	
	t	388.0	438.0	488.0	538.0	588.0	638.0	688.0	t	
215	v	2.14	2.33	2.51	2.68	2.84	3.00	3.16	v	215
	h	1199.2	1231.6	1259.0	1284.6	1309.7	1334.4	1359.1	h	
	t	389.9	439.9	489.9	539.9	589.9	639.9	689.9	t	
220	v	2.09	2.28	2.45	2.62	2.78	2.94	3.10	v	220
	h	1199.6	1232.2	1259.6	1285.2	1310.3	1335.1	1359.8	h	
	t	391.9	441.9	491.9	541.9	591.9	641.9	691.9	t	
225	v	2.05	2.23	2.40	2.57	2.72	2.88	3.03	v	225
	h	1199.9	1232.7	1260.2	1285.9	1310.9	1335.7	1360.3	h	
	t	393.8	443.8	493.8	543.8	593.8	643.8	693.8	t	
230	v	2.00	2.18	2.35	2.51	2.67	2.82	2.97	v	230
	h	1200.2	1233.2	1260.7	1286.5	1311.6	1336.3	1361.0	h	
	t	395.6	445.6	495.6	545.6	595.6	645.6	695.6	t	
235	v	1.96	2.14	2.30	2.46	2.62	2.77	2.91	v	235
	h	1200.6	1233.8	1261.4	1287.1	1312.2	1337.0	1361.7	h	
	t	397.4	447.4	497.4	547.4	597.4	647.4	697.4	t	
240	v	1.92	2.09	2.26	2.42	2.57	2.71	2.85	v	240
	h	1200.9	1234.3	1261.9	1287.6	1312.8	1337.6	1362.3	h	
	t	399.3	449.3	499.3	549.3	599.3	649.3	699.3	t	
245	v	1.89	2.05	2.22	2.37	2.52	2.66	2.80	v	245
	h	1201.2	1234.8	1262.5	1288.2	1313.3	1338.2	1362.9	h	
	t	401.0	451.0	501.0	551.0	601.0	651.0	701.0	t	
250	v	1.85	2.02	2.17	2.33	2.47	2.61	2.75	v	250
	h	1201.5	1235.4	1263.0	1288.8	1313.9	1338.8	1363.5	h	
	t	402.8	452.8	502.8	552.8	602.8	652.8	702.8	t	
255	v	1.81	1.98	2.14	2.28	2.43	2.56	2.70	v	255
	h	1201.8	1235.9	1263.6	1289.3	1314.5	1339.3	1364.1	h	

t = Temperature, degrees Fahrenheit.
v = Specific volume, in cubic feet, per pound.
h = Total heat from water at 32 degrees, B. t. u.



686 HORSE-POWER BABCOCK & WILCOX BOILER AND SUPERHEATER IN COURSE OF ERECTION AT THE QUINCY, MASS., STATION OF THE BAY STATE STREET RAILWAY CO.

THE ADVANTAGES OF THE USE OF SUPERHEATED STEAM

THAT there are advantages to be secured through the use of superheated steam is probably most conclusively shown by the fact that superheaters are installed, almost without exception, in the largest and most economical power plants throughout the world. Regardless of any such evidence, however, there is a deep-rooted conviction in the minds of certain engineers that the use of superheated steam will involve operating difficulties which, taken in connection with the added first cost, will more than offset any fuel saving. There are, of course, conditions under which the installation of superheaters would be in no way advisable. While such instances are perhaps rare, nevertheless, when a superheater installation is contemplated, it must be considered in all of its phases. The actual saving possible by the use of superheated steam must be balanced against such factors as the initial cost and upkeep of the superheater, the efficiency of the design of superheater to be installed, the nature of the service of the plant in question, the design of the prime movers, a consideration of pipe and fittings, and the like.

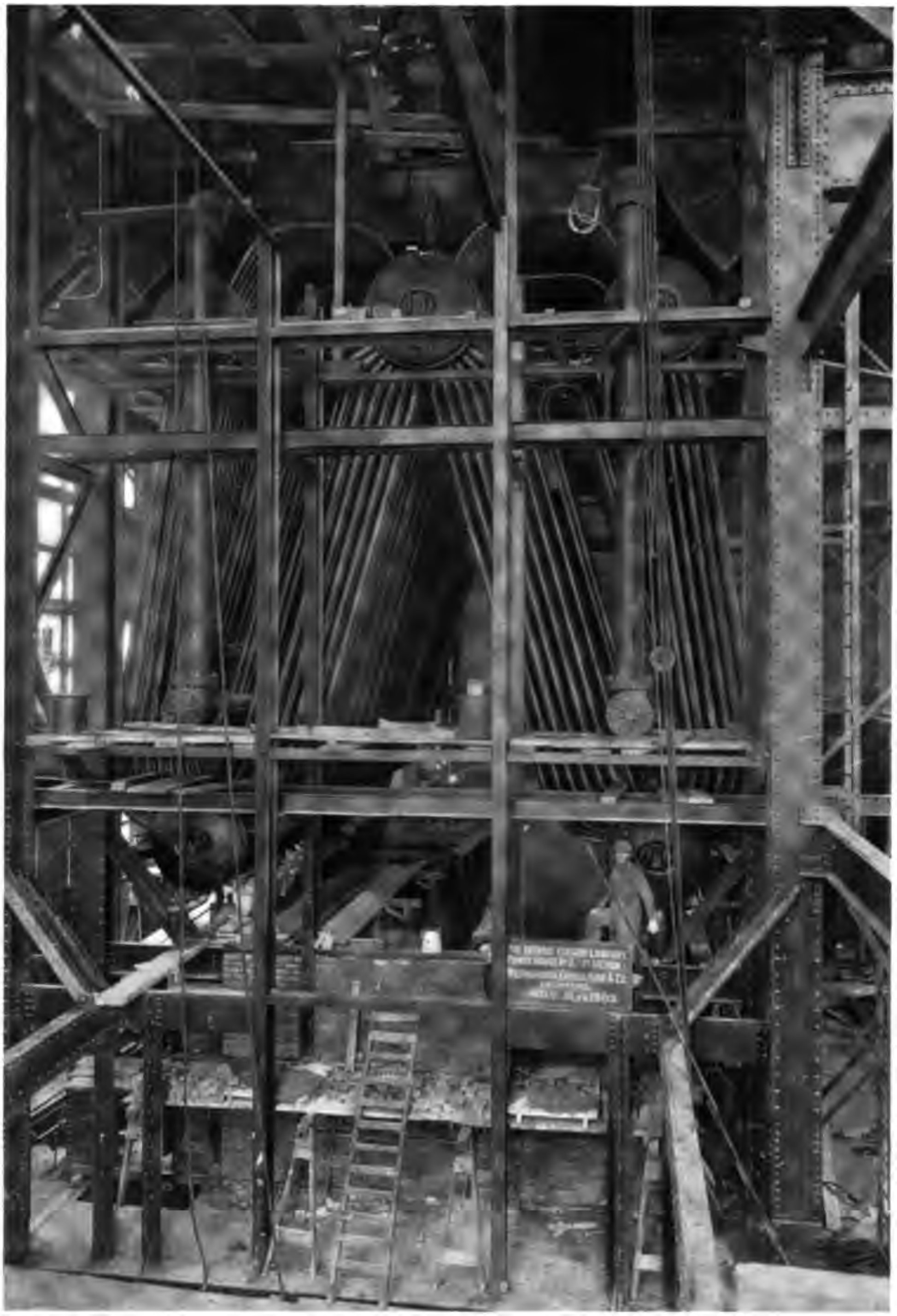
No general statement of the saving possible may be made since this may vary widely with a number of the factors above enumerated.

The logical method of approaching the subject would appear to be, first, a consideration of the saving in fuel possible through the use of superheated steam regardless of other factors; and, second, a consideration of the bearing of such factors on the advisability of a superheater installation.

In considering the saving possible by the use of superheated steam, it is too often assumed that there is only a saving in the prime movers, a saving which is at least partially offset by an increase in the fuel consumption of the boilers generating steam. This misconception is due to the fact that the fuel consumption of the boiler is only considered in connection with a definite weight of steam. It is true that where such a definite weight is to be superheated, an added amount of fuel must be burned. With a properly designed superheater, where the combined efficiency of the boiler and superheater will be at least as high as of a boiler alone, the approximate increase in coal consumption for producing a given weight of steam will be as follows:

Superheat Degrees	Added Fuel Per Cent	Superheat Degrees	Added Fuel Per Cent
25	1.59	100	5.69
50	3.07	150	8.19
75	4.38	200	10.58

These figures represent the added fuel necessary for superheating a definite weight of steam to the number of degrees given. A heat unit basis is standard in the consideration of boiler evaporation and from this standpoint, again providing the efficiency of the boiler and superheater is as high as of the boiler



BABCOCK & WILCOX SUPERHEATER AND STIRLING BOILER IN COURSE OF ERECTION AT THE DELRAY, MICH., STATION OF THE EDISON ELECTRIC ILLUMINATING CO., OF DETROIT. THIS COMPANY HAS BABCOCK & WILCOX SUPERHEATERS INSTALLED IN 29,500 HORSE POWER OF STIRLING BOILERS

alone, there is no additional fuel required to generate steam containing a definite number of heat units whether such units be due to superheat or saturation. That is, if 6 per cent more fuel is required to generate and superheat to 100 degrees a definite weight of steam, over what would be required to produce the same weight of saturated steam, that steam, when superheated, will contain 6 per cent more heat units above the feed water temperature than if saturated.

The statement that for an additional number of heat units generated in the furnace of a boiler equipped with a superheater, there will be an equivalent increase in the number of heat units appearing in the superheated steam over saturated, is based, as indicated, upon an equal efficiency for the boiler and superheater as for the boiler in which no superheater is installed. As a matter of fact, the efficiency of a boiler and superheater, where the latter is properly designed and located, will be slightly higher for the same set of furnace conditions than would be the efficiency of a boiler in which no superheater were installed. A superheater, properly placed within the boiler setting in such a way that the products of combustion for generating saturated steam are utilized as well for superheating that steam, will not in any way alter furnace conditions. With a given set of such furnace conditions, for a given amount of coal burned, the fact that additional surface, whether as boiler heating or superheating surface, is placed in such a manner that the gases must sweep over it, will tend to lower the temperature of the exit gases. It is such a lowering of exit gas temperature that is the ultimate indication of added efficiency. Though the amount of this added efficiency is difficult to determine by test, that there is an increase is unquestionable.

Where a properly designed superheater is installed in a boiler, the boiler heating surface, in the generation of a definite number of heat units, is relieved of a portion of the work which would be required were these heat units delivered in saturated steam. This results either in a reduction in the capacity at which it is necessary to operate the boiler itself, apart from the superheater, in the developing of a definite number of boiler horse power, with a consequent saving in the apparatus due to a decreased load, or it enables the same number of horse power to be developed from a smaller number of boilers, with the boiler heating surface doing the same amount of work as if no superheaters were installed. Such a superheater needs practically no attention, is not subject to a large upkeep cost or depreciation, and performs its function without in any way interfering with the operation of the boiler.

Following the course of the steam in the plant, the advantage of the use of superheated steam is next seen in the general absence of water in the pipes. While it is possible for a pipe through which superheated steam is flowing to also carry water, there is usually an entire absence of such water in the piping system, especially where the piping is well covered. The thermal conductivity of superheated steam, that is, its power to receive from or to give out heat to surrounding bodies, is much lower than that of saturated steam and its heat, therefore,

SINGER BUILDING, NEW YORK CITY. BABCOCK & WILCOX SUPERHEATERS INSTALLED IN 1940 HORSE POWER OF BABCOCK & WILCOX BOILERS

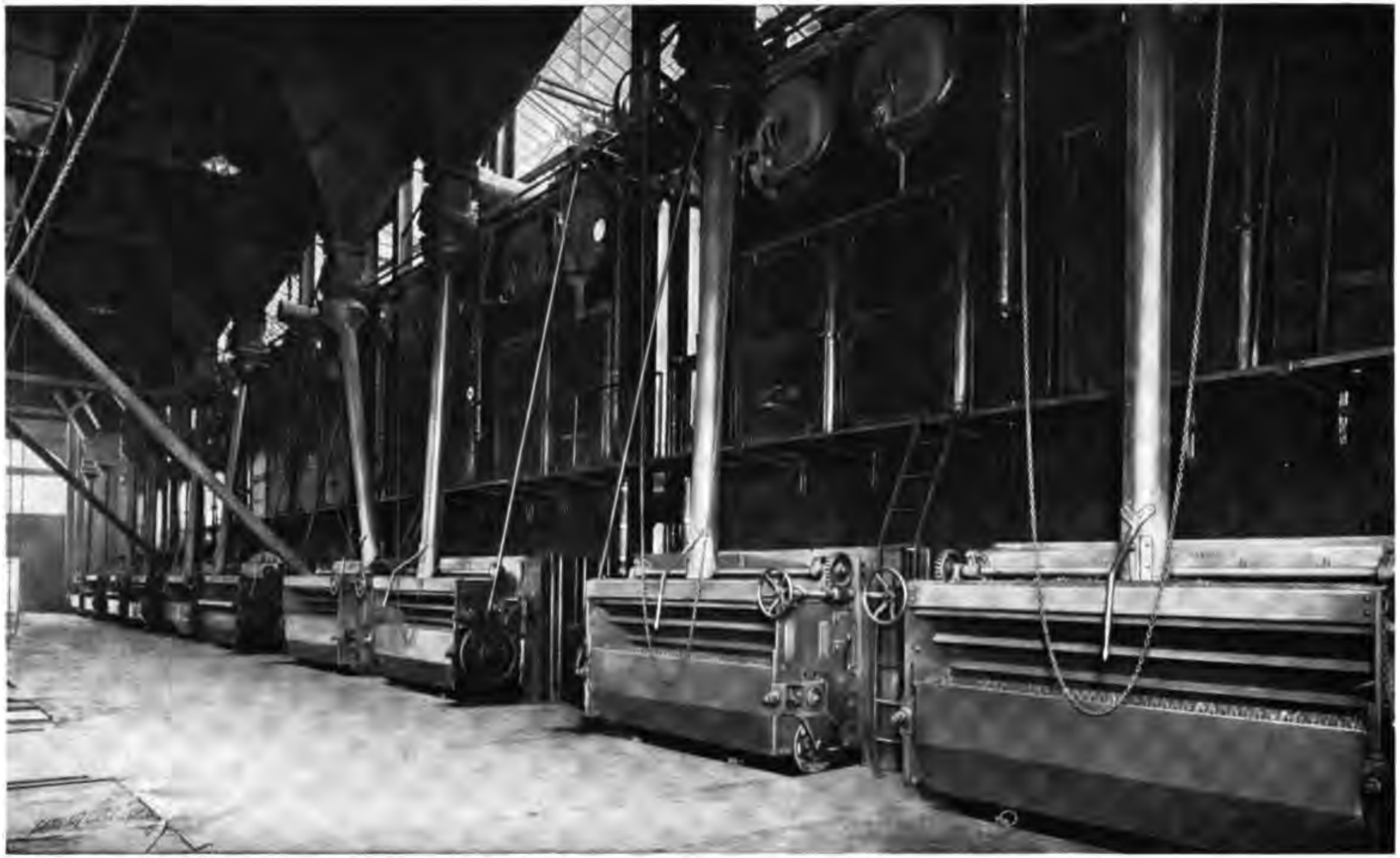
will not be transmitted so rapidly to the walls of the pipe as would the heat from saturated steam. When a pipe is carrying saturated steam, assuming no loss in pressure, the amount of heat radiated usually represents an equivalent condensation. Where such a pipe carries superheated steam, again assuming no loss in pressure, the amount of radiation represents only a decrease in the amount of superheat, for condensation cannot take place until the temperature of the steam is lowered to that of the saturated steam at the existing pressure and the temperature of the walls is higher than the temperature of saturated steam where the pipes are well covered and the steam is superheated an ordinary amount. Obviously, therefore, where the degree of superheat is sufficiently high at the boiler, an amount of heat could be radiated far in excess of what is found in well covered steam lines, and the steam as delivered to the prime movers and auxiliaries would still be dry or superheated.

The loss through drips resulting from such line condensation in the average plant using saturated steam is one which is ordinarily largely under-estimated. Such a loss, which is frequently in excess of 5 per cent, can be greatly reduced, if not entirely eliminated, where superheated steam is used.

It is in the prime movers that the advantages of the use of superheated steam are most clearly seen.

In an engine, steam is admitted into a space that has been cooled by the steam exhausted during the previous stroke. The heat necessary to warm the cylinder walls from the temperature to which they have been reduced by the exhaust can be supplied, in the absence of jackets, only by the entering steam, and even where jackets are used a large amount of heat must be supplied in this way. If this steam be saturated, such an adding of heat to the walls at the expense of the heat of the entering steam results in the condensation of a portion. This initial condensation is seldom less than from 20 to 30 per cent of the total weight of steam entering the cylinder. It is obvious that if the steam entering be superheated, it must be reduced to the temperature of saturated steam at a corresponding pressure before any condensation can take place. If the steam be superheated sufficiently to allow a reduction in temperature equivalent to the quantity of heat that must be imparted to the cylinder walls and still remain superheated, it is clear that initial condensation is avoided. In the case of a simple engine, where the range of temperature change is a maximum, the degree of superheat necessary to offset a cylinder condensation of, say, 20 per cent in the case of saturated steam, would be excessive, notwithstanding the lower conductivity of superheated steam. As cylinders are added, however, the range of temperature change between the entering steam and the cylinder walls is decreased and proportionately the degree of superheat necessary to prevent initial condensation.

With saturated steam the heat utilized in warming the cylinder walls to the temperature of the entering steam is mainly lost, insofar as its ability to perform work in the cylinder is concerned. It is true that as expansion progresses a



PUBLIC SERVICE CO. OF NORTHERN ILLINOIS, BLUE ISLAND, ILL., PLANT. BABCOCK & WILCOX SUPERHEATERS INSTALLED IN 9600 HORSE POWER OF BABCOCK & WILCOX BOILERS AT THIS STATION. THIS COMPANY HAS BABCOCK & WILCOX SUPERHEATERS INSTALLED IN 12,600 HORSE POWER OF BOILERS IN ITS VARIOUS STATIONS

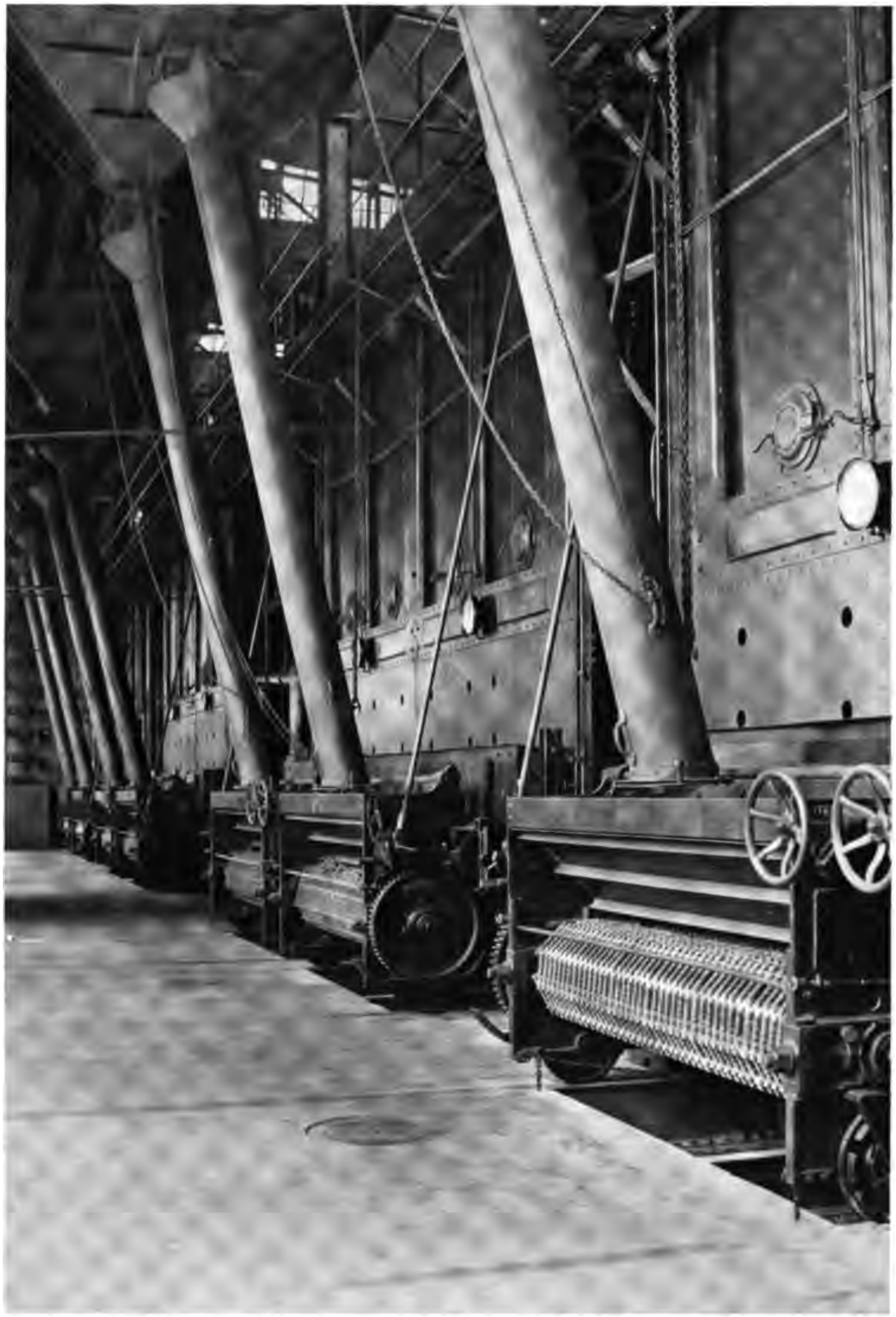
portion of the steam that has been so condensed will re-evaporate, though the greater portion of such re-evaporation takes place at the point of exhaust. The latent heat of the water given up in re-evaporation is utilized in changing the condition of the working fluid and is not available for work. Furthermore, a portion of the saturated steam condenses during adiabatic expansion, this condensation increasing as expansion progresses. In high speed engines using saturated steam the condensation due to adiabatic expansion is just about offset by the re-evaporation of the initial condensation. Since superheated steam cannot condense until its temperature has been reduced to that of saturated steam at a corresponding pressure, not only is initial condensation prevented by its use but also such condensation as would occur during expansion. When superheated sufficiently, the steam delivered by the exhaust will be dry. The number of heat units lost in overcoming condensation effects will be the same whether superheated or saturated steam is the working fluid, but in the case of saturated steam the water of condensation has no power to do work, while superheated steam, even after having given up the equivalent number of heat units to correspond to the condensation in the case of saturated steam, would still have the power of expansion and the ability to do work.

With superheated steam, therefore, a larger proportion of the heat is utilized in the developing of power than with saturated steam, where a large amount is lost in changing the condition of the working fluid. This results in a lower heat consumption in an engine using superheated steam, that is, the expenditure of a less number of heat units in the developing of one indicated horse power. The "heat consumption" furnishes the true basis for the comparison of efficiencies of different engines, just as a comparison of boiler results is based on an evaporation from and at 212 degrees.

The water consumption of an engine in pounds per indicated horse power is in no sense a true indication of its efficiency. The initial pressures and corresponding temperatures in two different cases may vary widely and thus through the resulting difference in the temperature of the exhaust affect the temperature of condensed steam returned to the boiler.

The lower the heat consumption of an engine per indicated horse power, the higher its economy. Since the use of superheated steam decreases this heat consumption, as has been shown, the number of heat units to be imparted in generating steam is reduced, this in turn leading to the lowering of the amount of fuel which must be burned.

No accurate statement can be made as to the saving possible through the use of superheated steam with reciprocating engines. In highly economical plants, where the water consumption per indicated horse power is low, the gain would be less than would result from the use of superheated steam in less economical plants where the water consumption is higher. Broadly speaking, it may vary from 3 to 5 per cent for 100 degrees of superheat in large and economical plants using engines in which there is a high ratio of expansion, to from 10 to 25 per cent



EDWARD FORD PLATE GLASS CO., ROSSFORD, OHIO. PORTION OF 4000 HORSE-POWER INSTALLATION OF STIRLING BOILERS, EQUIPPED WITH BABCOCK & WILCOX SUPERHEATERS

for 100 degrees of superheat where less economical steam motors are in service.

Experience has unquestionably shown that the use of superheated steam with turbines leads to an appreciable gain in economy. This fact is so well established that engineering practice does not countenance the installation of turbines for use with saturated steam.

Where saturated steam is used with turbines, even when it is dry upon entering the first stage, the work done in expanding the steam through progressive stages causes the condensation of a sufficient amount of steam to give trouble through the presence of water in the low pressure stages. When the entering steam is superheated, the amount of water in low pressure stages of the turbine is reduced to a point where no trouble will be caused.

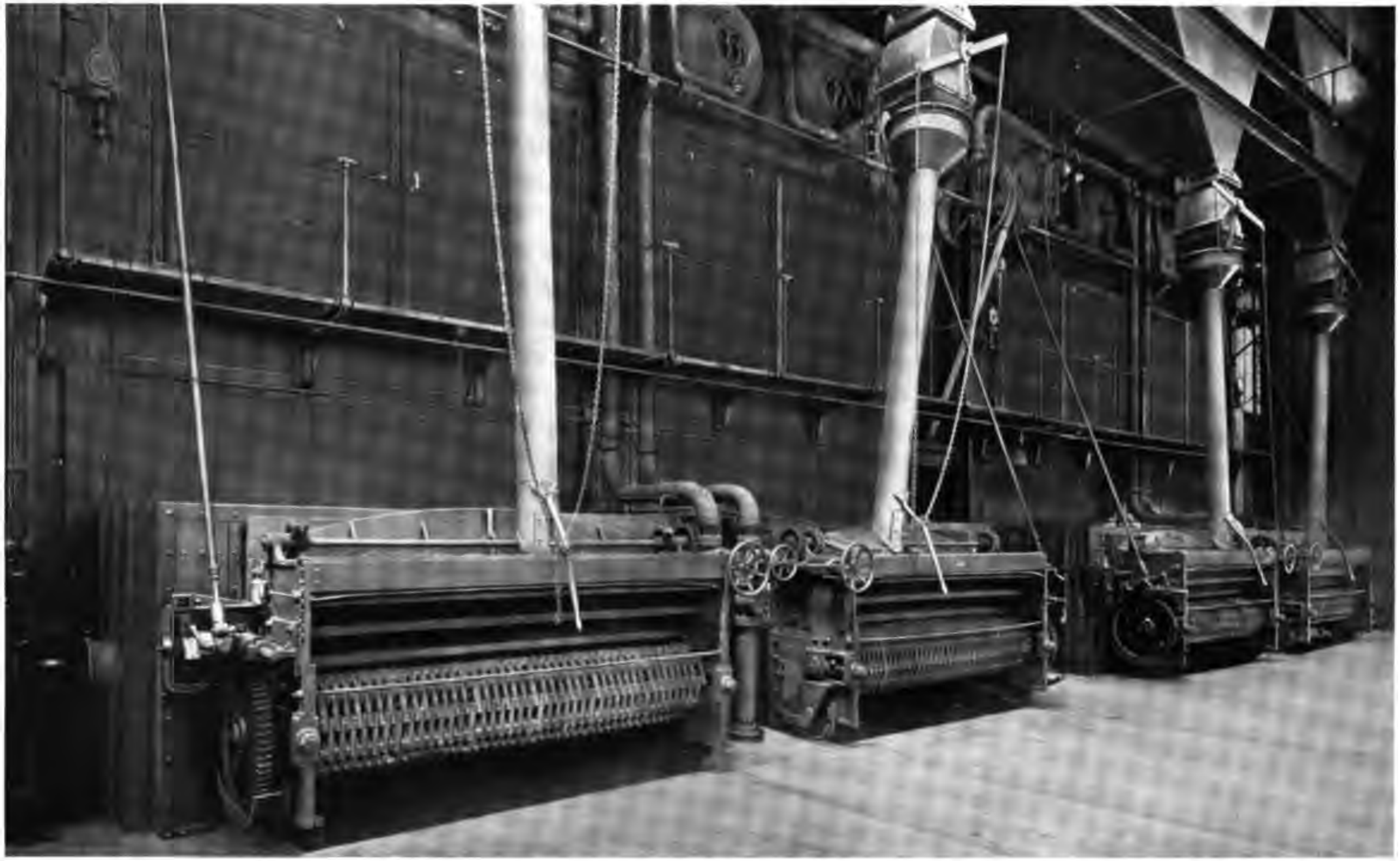
If the saturated steam entering a turbine contains moisture, the effect of such moisture is an appreciable lowering of the turbine's economy. It is stated on good authority that one per cent of moisture contained in the steam will reduce the economy approximately 2 per cent.

The water rate of a large economical steam turbine with superheated steam is reduced about one per cent for every 12 degrees of superheat up to 200 degrees of superheat. To superheat one pound of steam 12 degrees requires about 7 B. t. u. and if 1050 B. t. u. are required at the boiler to evaporate one pound of water into saturated steam from the temperature of the feed water, the heat required for the superheated steam would be 1057 B. t. u. One per cent of saving, therefore, in the water consumption would correspond to a net saving of about one-third of one per cent in the coal consumption. On this basis 100 degrees of superheat with an economical steam turbine would result in somewhat over 3 per cent of saving in the coal for equal boiler efficiencies. As a boiler with a properly designed superheater placed within the setting is more economical for a given capacity than a boiler without a superheater, the minimum gain in the coal consumption would be, say, 4 or 5 per cent as compared to a plant with the same boilers without superheaters.

The above estimates are on the basis of a thoroughly dry saturated steam or steam just at the point of being superheated or containing a few degrees of superheat. If the saturated steam is moist, the saving due to superheat is more, and ordinarily the gain in economy due to superheated steam for equal boiler efficiencies, as compared with commercially dry steam is, say, 5 per cent for each 100 degrees of superheat.

Aside from any thermodynamic gain through the use of superheated steam with turbines, there is an objection to the use of saturated steam from the standpoint of turbine construction. If saturated steam is used, the erosion of the turbine buckets by water carried in the steam may become a serious factor, while with superheated steam this is negligible.

For any type of steam motor it may be broadly stated that the lower its economy, the greater the saving that will be effected through the use of superheat.



LOUISVILLE GAS & ELECTRIC CO., LOUISVILLE, KY. BABCOCK & WILCOX SUPERHEATERS INSTALLED IN 4000 HORSE POWER OF BABCOCK & WILCOX BOILERS

The figures that have been given refer to the possible saving through the use of superheated steam in the prime movers alone. Where the auxiliaries are of a design that can properly handle superheated steam there will be a larger percentage of gain than in the prime movers. This is due to the fact that it is the auxiliaries in a plant that ordinarily show the lowest economy and the lower the efficiency of the steam apparatus, the greater the saving possible.

An example from actual practice will perhaps best illustrate and emphasize the foregoing facts. In October, 1909, a series of comparable tests were conducted by The Babcock & Wilcox Co. on the steam yacht "Idalia" to determine the steam consumption both with saturated and superheated steam of the main engine on that yacht, including as well the feed pump, circulating pump and air pump. These tests are more representative than are most tests of like character in that the saving in the steam consumption of the auxiliaries, which were much more wasteful than the main engine, formed an important factor. A résumé of these tests was published in the Journal of the Society of Naval Engineers, November, 1909.

The main engine of the "Idalia" is four cylinder, triple expansion $11\frac{1}{2}$ x 19 x $22\frac{1}{16}$ x 18 inches stroke. Steam is supplied by a Babcock & Wilcox marine boiler having 2500 square feet of boiler heating surface, 340 square feet of superheating surface and 65 square feet of grate surface.

The auxiliaries consist of a feed pump 6 x 4 x 6 inches, an independent air pump 6 x 12 x 8 inches, and a centrifugal pump driven by a reciprocating engine $5\frac{7}{16}$ x 5 inches. Under ordinary operating conditions the superheat existing is about 100 degrees Fahrenheit.

Tests were made with various degrees of superheat, the amount being varied by by-passing the gases, and in the tests with the lower amounts of superheat by passing a portion of the steam from the boiler to the steam main without passing it through the superheater. Steam temperature readings were taken at the engine throttle. In the tests with saturated steam, the superheater was completely cut out of the system. Careful calorimeter measurements were taken, showing that the saturated steam delivered to the superheater was dry.

The weight of steam used was determined from the weight of the condensed steam discharged from the surface condenser, the water being pumped from the hot well into a tank mounted on platform scales. The same indicators, thermometers and gauges were used in all the tests so that the results are directly comparable. The indicators used were of the outside spring type so that there was no effect of the temperature of the steam. All tests were of sufficient duration to show a uniformity of results by hours. A summary of the results secured is given in Table 2, which shows the water rate per indicated horse power and the heat consumption. The latter figures are computed on the basis of the heat imparted to the steam above the actual temperature of the feed water, and, as stated, these are the figures that are directly comparable.

NEW YORK EDISON CO., NEW YORK CITY. WATERSIDE STATIONS NOS. 1 AND 2. BABCOCK & WILCOX SUPERHEATERS INSTALLED IN 95,000 HORSE POWER OF BABCOCK & WILCOX BOILERS IN THESE STATIONS

The table shows that the saving in steam consumption with 105 degrees of superheat was 15.3 per cent and in heat consumption about 10 per cent. This may be safely stated to be a conservative representation of the saving that may be accomplished by the use of superheated steam in a plant as a whole,

TABLE 2

RESULTS OF "IDALIA" TESTS

Date		1909	Oct. 11	Oct. 14	Oct. 14	Oct 12	Oct. 13
Degrees of Superheat Fahrenheit			0	57	88	96	105
Pressures, pounds per square inch above Atmospheric Pressure	Throttle		190	196	201	198	203
	First Receiver		68.4	66.0	64.3	61.9	63.0
	Second Receiver		9.7	9.2	8.7	7.8	8.4
Vacuum, inches			25.5	25.9	25.9	25.4	25.2
Temperature, Degrees Fahrenheit	Feed		201	206	205	202	200
	Hot Well		116	109.5	115	111.5	111
Revolutions per minute	Air Pump		57	56	53	54	45
	Circulating Pump		196	198	196	198	197
	Main Engine		194.3	191.5	195.1	191.5	193.1
Indicated Horse Power, Main Engine			512.3	495.2	521.1	498.3	502.2
Water per hour, total pounds			9397	8430	8234	7902	7790
Water per indicated Horse Power, pounds			18.3	17.0	15.8	15.8	15.5
B. t. u. per minute per indicated Horse Power			314	300	284	286	283
Per cent Saving of Steam			. .	7.1	13.7	13.7	15.3
Per cent Saving of Fuel (computed)			. .	4.4	9.5	8.9	9.9

where superheated steam is furnished not only to the main engine but also to the auxiliaries. The figures may be taken as conservative for the reason that in addition to the saving as shown in the table, there would be in an ordinary plant a saving much greater than is generally realized in the drips, where the loss with saturated steam is greatly in excess of that with superheated steam.

That there is a saving possible through the use of superheated steam is clearly demonstrated by the foregoing discussion. A consideration of certain of the factors upon which the question of superheater installation is based follows, together with a discussion of certain objections that have been raised against such an apparatus.

Superheater Design — Though a properly designed superheater will tend to raise rather than decrease the efficiency of the boiler in which it is installed, it does not follow that all superheaters are efficient. There are a number of features to be observed in the design of integral superheaters.

If the gases in passing over the superheater do not follow the path they would ordinarily take in passing over the boiler heating surface, a loss may result. This is particularly true when a portion of the gases are passed directly to the superheater and are made to pass over only a portion of the boiler heating surface. While a location in the direct path of the gases is essential for superheater efficiency, from the standpoint of the boiler's operation this location and the arrangement of the superheating surface must be such as to cause no undue frictional resistance to the gases in their passage.

WORCESTER ELECTRIC LIGHT CO., WORCESTER, MASS. BABCOCK & WILCOX SUPERHEATERS INSTALLED IN 3600 HORSE POWER OF STIRLING BOILERS

The full surface of the superheater should be presented for contact with the gases, but the construction must be such as to offer no undue lodging place for the soot and dust that is carried by practically all gases.

All parts of the superheater should be readily accessible for inspection, cleaning and necessary repairs. The design should be such as to allow freedom of expansion without affecting the boiler proper or the setting.

All superheaters should be equipped with safety valves set slightly lower than the boiler valves. This is essential to provide a flow of steam through the superheater and prevent any overheating of the superheater in case the load should be suddenly thrown off the boiler or the plant. Safety valves for this purpose should be of the outside spring type, with steel bodies.

PIPING — With moderate degrees of superheat, not exceeding 200 degrees, with properly constructed piping, there will be no greater operating difficulties experienced than with saturated steam. Due to the higher temperatures present, proper care must be taken to allow for pipe expansion in order that there may be no undue strains. This is particularly true in a mixed plant, where superheated and saturated steam are both used. Under such conditions there will be portions of the piping where the steam at times will become saturated. Such portions will be reduced to the temperature of saturated steam and water will collect. When starting to draw superheated steam through such a dead pipe, due to a sudden increase in temperature, expansion strains will be set up that may lead to ruptured elbows or other connections in the line where proper allowance has not been made for such expansion.

FITTINGS — The question of the proper fittings to be used with superheated steam has been widely discussed. It is an undoubted fact that while in some instances superheated steam has caused deterioration of cast-iron fittings, in others, such fittings have been used with 150 degrees of superheat without difficulty. The quality of the cast iron used for the fittings has doubtless a large bearing on the life of such fittings for this service. The difficulties that have been encountered are distortion and an increase in the size of the fittings, with an eventual deterioration great enough to lead to serious breakage, the development of cracks, and, when flanges are drawn up too tightly, the breaking of a flange from the body of the fitting. The latter difficulty is undoubtedly due, in certain instances, to the form of flange in which the strain of the connecting bolts tended to distort the metal.

The Babcock & Wilcox Co. have used steel castings in superheated steam work over a long period and experience has shown that this metal is suitable for the service. There seems to be a general tendency toward the use of steel fittings. In European practice, until recently, cast iron was used with apparently satisfactory results. The claim of European engineers was to the effect that their cast iron was of a better quality than that found in this country and they thus explained the results secured. Recently, however, certain of the difficulties enumerated above have been encountered

QUARRY STREET STATION, COMMONWEALTH EDISON CO., CHICAGO, ILL. BABCOCK & WILCOX SUPERHEATERS INSTALLED IN 24,420 HORSE POWER OF BABCOCK & WILCOX BOILERS

with such fittings and European engineers are leaning toward the use of steel for this work.

FLUCTUATION OF SUPERHEAT—A given amount of superheating surface installed in a given boiler will give varying amounts of superheat for different furnace arrangements, for different fuels, and for different capacities at which the boiler may be operated. Due to this obvious fact, it is essential that in the designing of a superheater for a particular installation all of these factors be given proper consideration to assure the furnishing of the right amount of surface to secure the desired results.

Further, a definite arrangement of superheater, boiler and furnace will give varying amounts of superheat under varying conditions of fire, load and operation, this being necessarily true of a superheater swept by the main body of the products of combustion. While this is a fact that should be appreciated by the prospective user of superheated steam, with a properly designed superheater the variation in superheat will not be excessive and momentary fluctuations, with proper operation, may be reduced to a negligible amount.

As a matter-of-fact, the point to be guarded against in the use of superheated steam is that a maximum should not be exceeded. While there may be slight momentary fluctuations in the temperature of steam delivered from individual superheaters, where there are a number of boilers on a line the temperature of the combined flow of steam in the main will be found to be practically a constant, resulting from the offsetting of various furnace conditions of one boiler by another.

When a superheater installation is contemplated in a plant already in operation, the builders of the steam motors there in use must be consulted as to the ability of their product to satisfactorily operate with superheated steam. In the case of new steam motors, manufacturers should specify the maximum amount of superheat with which their apparatus should be operated.

With high degrees of superheat, say, over 250 degrees, apparatus of a special nature may be necessary and it is questionable whether the additional cost, care and liability to operating difficulties will be offset by any fuel saving accomplished. It is well established, however, that with the degree of superheat to which this article is limited, 100 to 200 degrees, operating difficulties have been entirely overcome.

POTOMAC ELECTRIC CO., WASHINGTON, D. C. BABCOCK & WILCOX SUPERHEATERS INSTALLED IN 12,000 HORSE POWER OF BABCOCK & WILCOX BOILERS

BABCOCK & WILCOX SUPERHEATERS

SUPERHEATERS built by The Babcock & Wilcox Co. for installation in all boilers of their manufacture are similar in design, location and operation. As will be shown, there are conditions under which it is advisable to change the design of the superheaters for different boilers in certain details. The different styles of superheaters ordinarily supplied with different boilers of The Babcock & Wilcox Company's manufacture will be described in detail hereafter, the present description dealing only with the general features common to all classes.

The Babcock & Wilcox superheater consists ordinarily of two superheater headers, or manifolds, into which cold drawn, seamless steel tubes bent to a "U" shape are expanded.

Saturated steam is taken from the steam space of the boiler, introduced into the intake header, passes through the tubes and is taken from the outlet header.

The superheaters in all classes of boilers are so placed that the tubes are in the direct path of the gases and the steam is superheated in its passage through the tubes by the same gases which are utilized to generate the saturated steam.

The location in all boilers is such that the superheaters are readily accessible for inspection and repair. Handholes in the manifolds give easy access to the interior of the headers and these handholes are so located that all tubes and joints may be readily examined.

The number, grouping and length of tubes are varied to meet the requirements of the superheating surface necessary.

Expansion is taken care of by the form of the tubes together with the use of proper methods of suspension, there being no rigid connection between the manifolds.

All superheaters present smooth external surfaces which not only offer the least possible resistance to the flow of the gases of combustion but also the least opportunity for the adhesion and collection of dust or soot in quantities sufficient to interfere with the efficiency and uniform operation of the superheater. Such dust as may cling to the tube surfaces may be readily removed by means of a steam lance through doors in the setting furnished for that purpose.

No flanged joints are exposed to the gases, all tube joints being expanded and the tube ends flared.

All superheaters are provided with safety valves, the necessity of which has been shown.

No additional care of the boiler is required because of the installation of Babcock & Wilcox superheaters, and the cost of maintenance and operation is negligible.

With boilers in which it is possible to introduce the steam into the intake header of the superheater at several points and to provide several outlet connections, an even distribution of the steam through all of the tubes of the superheater

REPUBLIC IRON & STEEL CO., YOUNGSTOWN, OHIO. OPEN HEARTH PLANT 6000 HORSE-POWER INSTALLATION OF STIRLING BOILERS, EQUIPPED WITH BABCOCK & WILCOX SUPERHEATERS

is assured. Where it is possible to make only one inlet and one outlet connection to the superheater, it has ordinarily been found advisable to use a construction employing cores within the superheater tubes. It may be readily understood that if the total cross sectional area of the tubes is so great in proportion to that of the manifolds as to cause a marked decrease in the velocity of the steam through the tubes, there will be a tendency on the part of the steam to take the shortest course between the point of introduction and the outlet manifold. By the use of cores the ratio of the area through the tubes to that of the manifold may be made such as to assure all tubes carrying their proper proportion of steam under any conditions of operation.

The installation of cores in superheater tubes will cause a drop in pressure through the superheater due to the added friction resistance to the steam. This drop in pressure can be calculated for any set of conditions and when such a drop is kept within reasonable limits with the boiler operating at, say, 200 per cent of its rated capacity, it may be taken as an assurance that all tubes of the superheater are carrying their proportion of the steam. If the cores are not properly designed, their use may cause a drop in pressure through the superheater that is objectionable.

The method of installing cores and holding them in position in superheaters of this description will be described in detail later.

The cored type of superheater as manufactured by The Babcock & Wilcox Co. has given eminently satisfactory results in boilers where its use has been believed advisable.

BABCOCK & WILCOX SUPERHEATER AS ORDINARILY APPLIED TO BABCOCK & WILCOX BOILERS

BABCOCK & WILCOX SUPERHEATERS

AS APPLIED TO BABCOCK & WILCOX BOILERS

THE general features in the design of the Babcock & Wilcox superheater as applied to all boilers of this company's manufacture have been briefly described. There follows a detailed description of this superheater as applied to individual boilers.

BABCOCK & WILCOX BOILERS

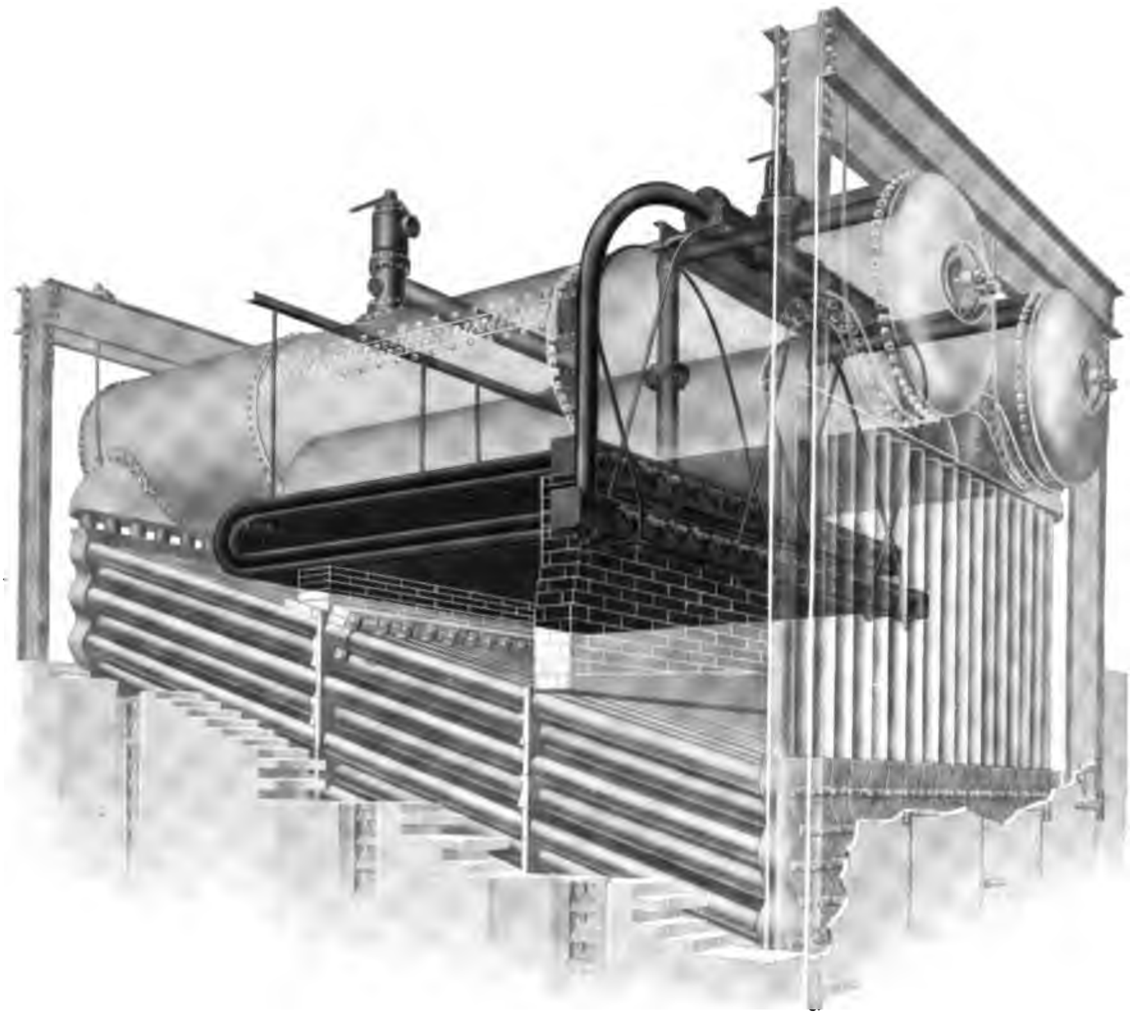
CONSTRUCTION—The superheater as applied to the Babcock & Wilcox boiler is formed of two transverse, square, wrought-steel boxes or manifolds into which 2-inch, cold drawn, seamless steel tubes, bent to a "U" shape, are expanded. By variation in the length and number of these tubes, the requisite amount of superheating surface and cross sectional area for the flow of steam is provided. The tubes ordinarily are arranged in groups of four and opposite the ends of each group an elliptical handhole is provided giving access for expanding or inspection. The handholes are machine faced and milled back from the inside edge of the box a sufficient distance to make a seat. The openings are closed on the inside by forged-steel handhole plates shouldered to center in the opening, the flanged seats being milled to a true plane. These plates are held in position by fixed studs and forged-steel binders and nuts. The joints between superheater boxes and plates are made with a thin gasket.

FORGED-STEEL ELLIPTICAL SUPERHEATER HAND-HOLE FITTINGS

CROSS SECTION OF SUPERHEATER HEADER SHOWING HANDHOLE FITTINGS ASSEMBLED

The superheater is located in the triangular space below the boiler drums and above the inclined tubes. Steam flows from the dry pipes located within the drums near their tops through 4-inch tubes which pass through internal and external pads at the bottom of the drum shell, into a section of the inlet or distributing superheater header or box, these tubes being expanded into the pads and the box. The inlet superheater header is divided into as many sections as there are drums to avoid strains due to expansion.

From the outlet header, which is continuous, the superheated steam flows through other 4-inch tubes to a cast-steel superheater center fitting supported over the drums. The connections between these outlet tubes and center fitting



PHANTOM VIEW OF BABCOCK & WILCOX SUPERHEATER AS ORDINARILY INSTALLED IN BABCOCK & WILCOX BOILERS, SHOWING LOCATION, METHOD OF SUPPORT AND METHOD OF MAKING INLET AND OUTLET CONNECTIONS

are made by extra heavy wrought-steel flanges into which the tubes are expanded, the flanges being bolted to corresponding flanges on the center fitting. The superheater center fitting is provided with a standard extra heavy flanged superheated steam outlet and with an extra heavy flange for the reception of a superheater safety valve. This safety valve is furnished as a part of the regular equipment and is steel bodied, of the outside spring type, set 2 pounds lower than the safety valves of the boiler. The necessity for safety valves with superheaters has been shown.

Circular handholes, closed by forged-steel, inside fitting plates, give access to all expanded joints of the connecting tubes.

For equalizing the pressure between the drums and the superheater center fitting, when the discharge from the superheater is closed, a small equalizing pipe is furnished connecting the center fitting to the saturated steam space in the drum, thus breaking any vacuum which might be formed in the center fitting, causing it to be filled with water.

CIRCULAR HANDHOLE FITTINGS FOR ACCESS TO SUPERHEATER INLET AND OUTLET CONNECTIONS

Location—As stated, the superheater is located in the triangular space below the drums and above the inclined tubes. The headers, or manifolds, are built into the brickwork of the hanging bridge wall, bringing the handhole fittings above the third pass of the boiler where they are exposed to only moderate temperatures.

The "U" form of the tubes and the absence of joints in the direct path of the gases, made possible by the location described, give the best possible conditions to assure the absence of stresses tending to leaky joints.

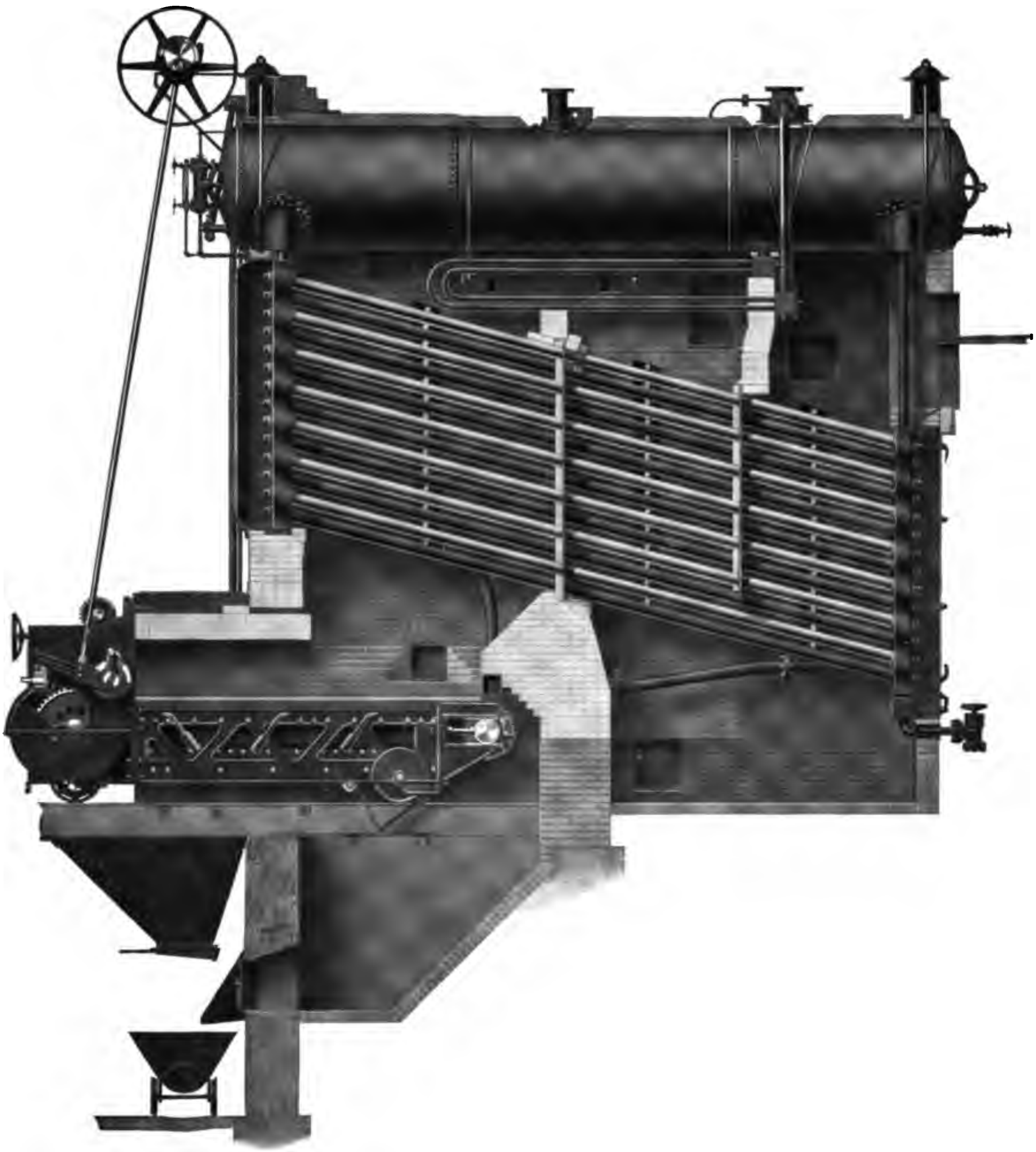
The location is such as in no way to interfere with the cleaning or repairing of the boiler proper.

Furthermore, this location of the superheater is such that the entire first pass of the boiler heating surface is between it and the fire and wide variation in the temperature of the gases sweeping over the superheating surface is thus avoided.

Supports — The forward ends of the superheater loops are supported temporarily, during erection, from the drums above by light angles and rods. These are left in place but are not depended upon for support as the tubes also rest on brickwork built above the front flame bridge of the boiler.

The lower superheater box is supported by "U" bolts passing over the drums.

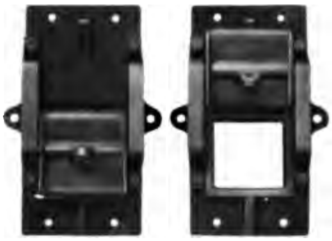
The superheater center fitting is carried on channels resting on pads on the drums.



BABCOCK AND WILCOX SUPERHEATER INSTALLED IN A WROUGHT-STEEL VERTICAL HEADER BABCOCK & WILCOX BOILER, EQUIPPED WITH A BABCOCK & WILCOX CHAIN GRATE STOKER

Accessibility — The means of access to the interior of the superheater boxes and to all expanded joints is through handholes, as has been described. These handholes are readily accessible from the space behind the hanging bridge wall above the third pass of the boiler.

A large cleaning door in the side wall of the boiler setting in front of the hanging bridge wall gives access to the space below, above and between the superheater tubes. Square superheater dusting doors in the side walls provide means of blowing any accumulation of dust from the superheater tubes.



SUPERHEATER DUSTING DOORS

Flooding Device — In the early design of the Babcock & Wilcox superheater as applied to Babcock & Wilcox boilers, a device was furnished for flooding the superheater during such time as steam was being raised. This was supplied as protection against the possible overheating of any superheater parts. While extended experience has shown that such a device is not a necessity, still it is furnished in a number of instances as a regular part of the superheater equipment simply as a super-precautionary means of protection. While The Babcock & Wilcox Co. recommend the use of a flooding device, they do not insist upon it.

Cores are sometimes used in Babcock & Wilcox superheaters when installed in Babcock & Wilcox boilers. This is done in special constructions where the employment of cores leads to a better steam distribution than would be obtained without their use.

BABCOCK & WILCOX SUPERHEATER AS ORDINARILY INSTALLED IN STIRLING AND RUST BOILERS

BABCOCK & WILCOX SUPERHEATERS

AS APPLIED TO STIRLING BOILERS

IN Stirling boilers the superheaters are placed directly behind the front bank of tubes below the middle drum. This location, relative to the pressure parts of the boiler, which is clearly indicated by the illustration, is covered by patents.

Owing to the method of introducing steam into the superheater when installed in this design of boiler, the cored type is ordinarily furnished.

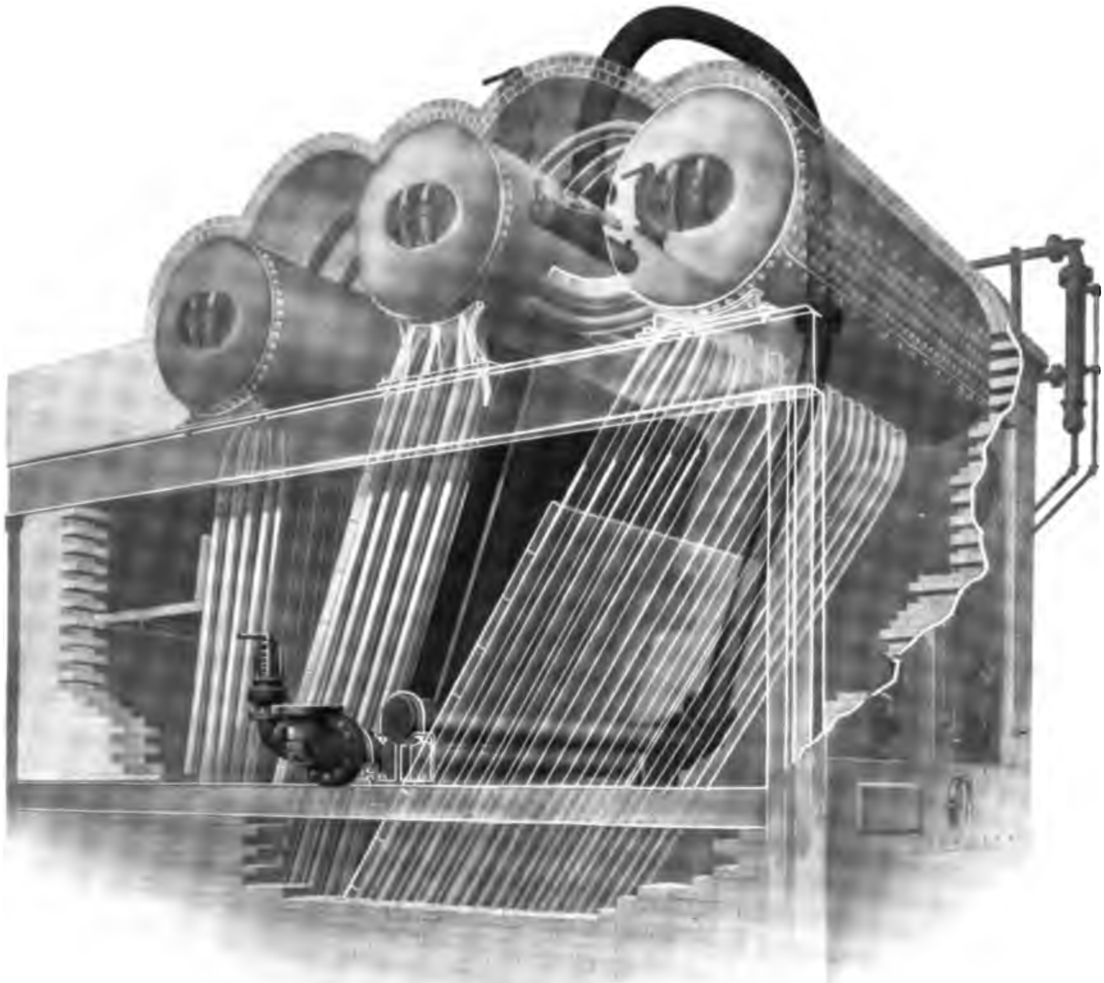
FORGED-STEEL ROUND SUPERHEATER HANDHOLE FITTINGS

CONSTRUCTION—The superheater headers are of extra heavy wrought-iron pipe of sufficient diameter to give the desired velocity of steam through this portion of the apparatus. The pipe is flattened top and bottom, as shown in the sectional view for that portion of its length inside the boiler walls or for the portion into which tubes are expanded, and handholes are provided.

CROSS SECTION SUPERHEATER HEADER SHOWING HANDHOLE FITTINGS ASSEMBLED AND METHOD OF HOLDING CORE IN PLACE

The tubes are 2-inch, cold drawn, seamless steel, bent to a "U" shape, expanded at the ends into bored seats in the upper flattened portion of the superheater headers. By a variation in the length and spacing of the tubes, the requisite amount of superheating surface is provided to give the desired degree of superheat.

Opposite each tube end in the lower flattened portion of the superheater header there is provided an individual circular handhole, which gives access to the end of the tube for expanding and for inspection. These handholes are machine faced back from the edge a sufficient distance to make a seat and are closed by circular, inside fitting, forged-steel handhole plates shouldered to center in the opening, the flanged seats being milled to a true plane. A ¾-inch bolt, forged integral with the handhole plate, extends through the opening and a wrought-steel crosspiece extending across the opening on the outside holds the plate in place. The bolt extending through this crosspiece receives



PHANTOM VIEW OF BABCOCK & WILCOX SUPERHEATER AS ORDINARILY INSTALLED IN STIRLING BOILERS, SHOWING LOCATION, METHOD OF SUPPORT AND METHOD OF MAKING INLET AND OUTLET CONNECTIONS

a cap nut which protects the threads from possible oxidization. The joints between header and handhole plates are made with thin gaskets.

Cores ordinarily made of No. 13 B. W. G. tubes, plugged at one end, are inserted in the straight portion of the 2-inch superheater tubes, causing the steam to flow through the annular space thus formed. By a variation in the diameter of these cores, the proper ratio of total cross sectional area through the tubes to that through the boxes may be secured. The cores are held central in the superheater tubes by projections formed in the cores for this purpose. This construction is clearly shown by the illustrations. The cores are maintained in their position lengthwise in the superheater tubes by similar projections which engage grooves rolled for the purpose in the tubes near their lower ends.

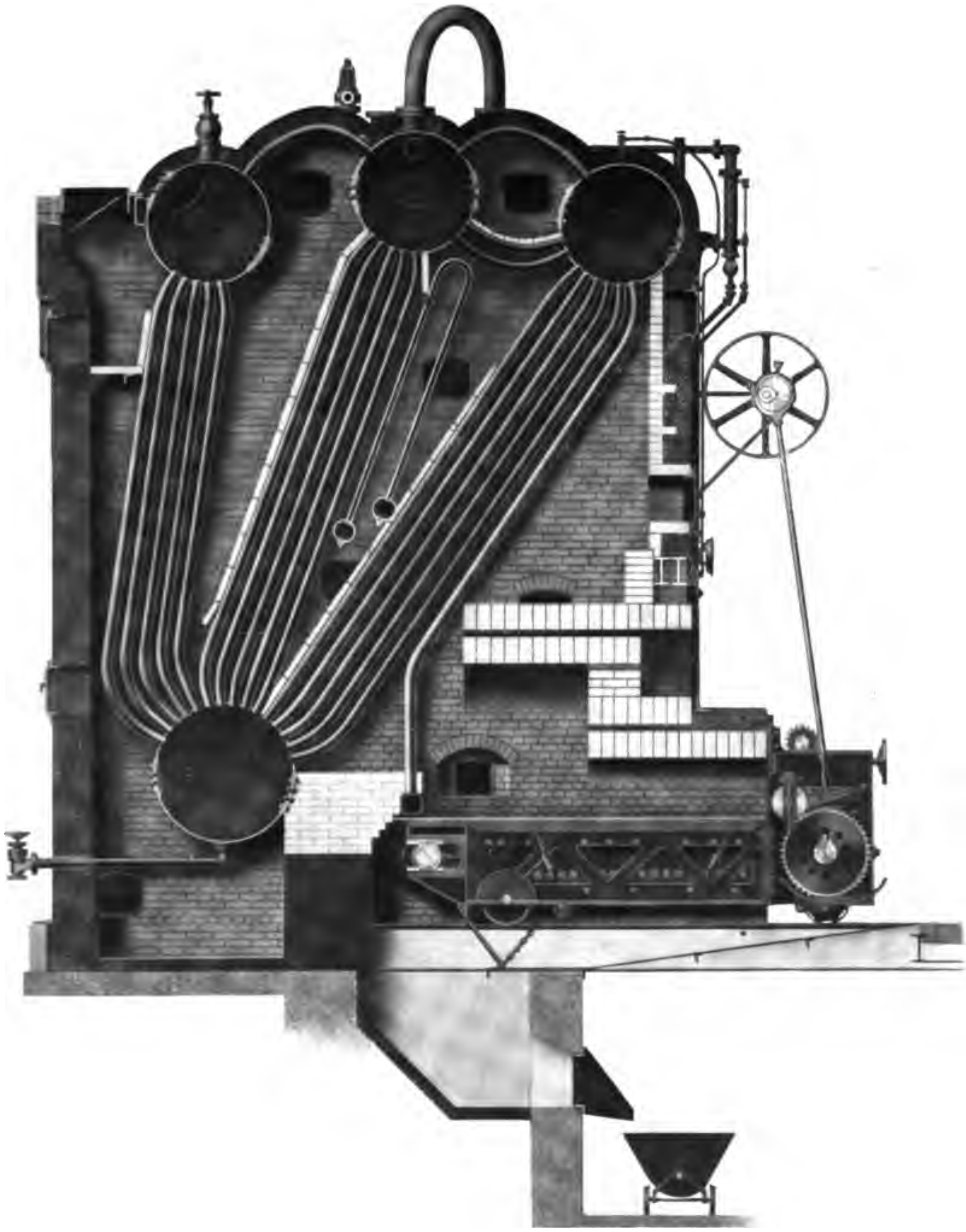
COLD DRAWN SEAMLESS STEEL SUPERHEATER TUBES

CORES FOR INSTALLATION IN SUPERHEATER TUBES

One end of each superheater header is welded closed. To the other end there is attached a wrought-steel flange. The pipe and flange are threaded, the pipe slightly expanded after the flange is screwed on, then peened over and faced.

Steam is taken through the boiler dry pipe from the saturated steam outlet on the center drum by means of tubes expanded at the ends into wrought-steel flanges. A special cast-steel flanged inlet elbow connects the intake pipe to the intake superheater header. The steam then passes through the tubes to the outlet header, to the flanged end of which is a special cast-steel superheated steam outlet fitting. This fitting has a standard extra heavy flanged outlet to which the superheated steam connection from the boiler is made. The superheater outlet fitting also has an extra heavy flange for the reception of a safety valve. The safety valve which is furnished as a part of the regular superheater equipment is steel bodied, of the outside spring type, and is set to blow at a pressure slightly lower than that at which the saturated steam safety valves of the boiler are set.

The inlet and outlet superheater fittings are provided with square handholes which give access to the ends of the superheater headers and to the inlet and outlet connections. These handholes are closed by square, inside fitting,



BABCOCK & WILCOX SUPERHEATER INSTALLED IN A STIRLING BOILER, EQUIPPED WITH A BABCOCK & WILCOX CHAIN GRATE STOKER

forged-steel handhole plates, which are held in position by forged-steel guards and nuts. The joints between handhole plates and inlet and outlet fittings are made with thin gaskets.

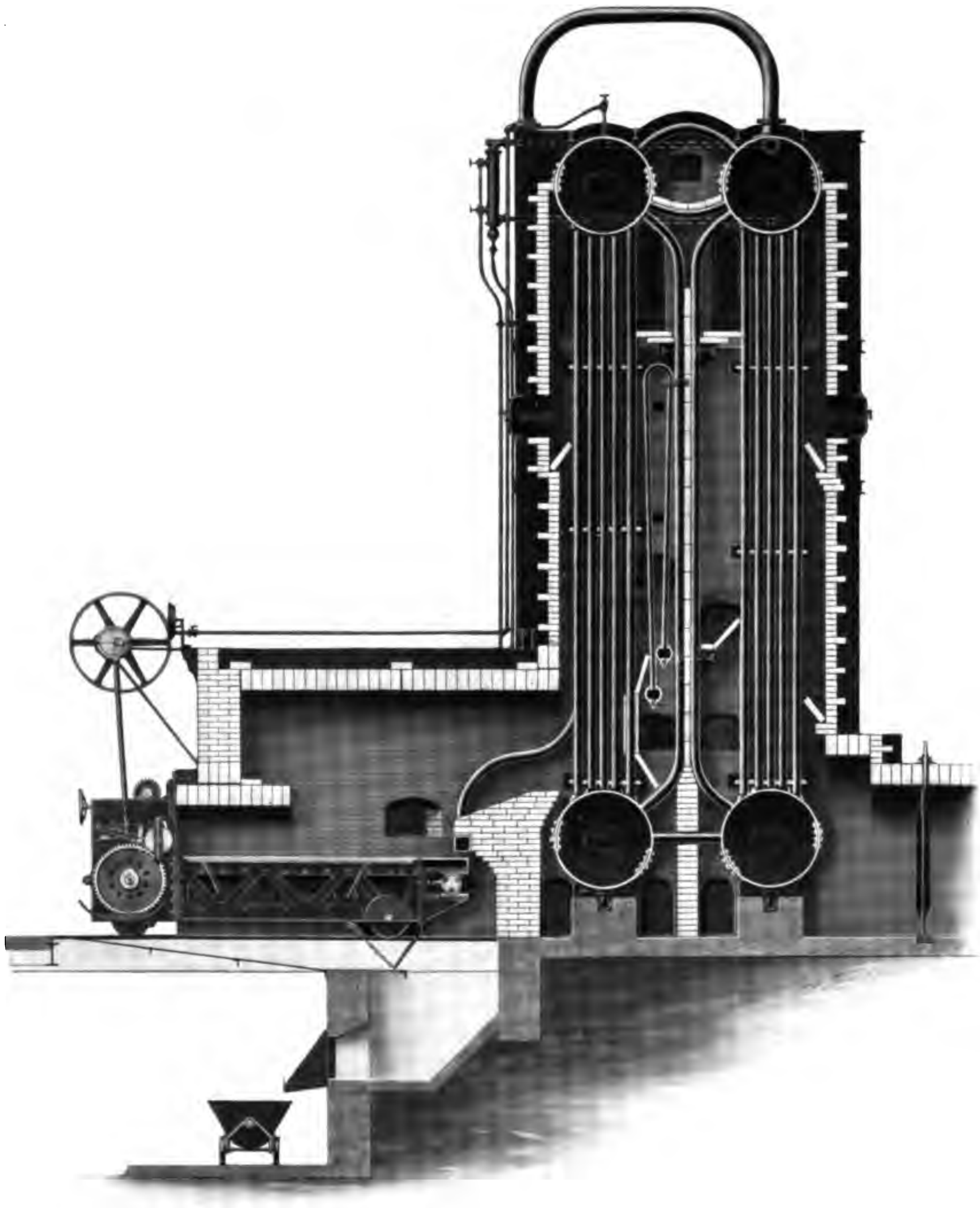
Drain pipes and valves are provided for draining any water that may collect in the superheater headers when no steam is passing through.

FORGED-STEEL SQUARE HANDHOLE FITTINGS SUPPLIED WITH INLET AND OUTLET SUPERHEATER CONNECTION ELBOWS

SUPPORTS — The superheater headers are carried at both ends on saddles attached to members which are framed into the boiler supporting structure. The overturning moment of the superheater is taken care of by straps attached to the saddles passing over the boxes at the ends. These hold the superheater in position and are so arranged as to allow for longitudinal expansion of the boxes.

LOCATION — As stated, the superheater is located in the triangular space beneath the center drum between the front and middle banks of tubes, thus allowing all of the gases to sweep evenly over the superheating surface after they have passed over the front bank of boiler tubes.

ACCESSIBILITY — Large doors in the side walls give access to the space under the superheater headers, from which inspection and repairs can be readily accomplished. Other doors give access to the space in front of and between the tubes and allow all parts of the superheater to be thoroughly cleaned.



BABCOCK & WILCOX SUPERHEATER INSTALLED IN A RUST BOILER, SHOWING LOCATION IN THE FRONT PASS

BABCOCK & WILCOX SUPERHEATERS

AS APPLIED TO RUST BOILERS

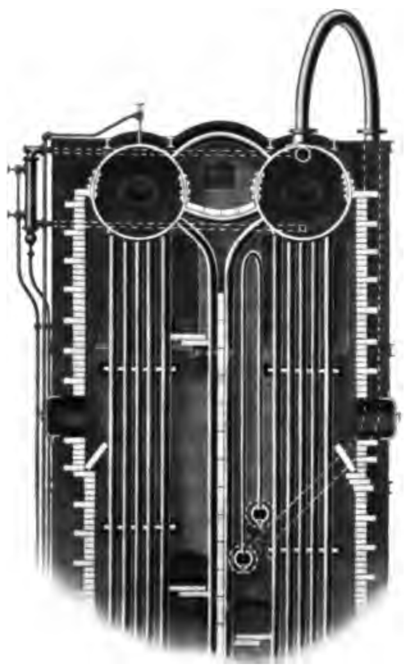
THE construction of the Babcock & Wilcox superheater as applied to Rust boilers is exactly similar to that used with Stirling boilers already described, the cored type of superheater being used exclusively.

Saturated steam is taken through a dry pipe from the rear steam drum by an outside connecting pipe to one end of the intake header and is removed from the outlet header by a single connection, either at the same or opposite end. Inlet and outlet elbows such as have been described are used for these connections.

SUPPORTS—The superheater headers are supported by channels or "I" beams, extending from front to rear of the boiler setting. In some instances both boxes are hung by straps from these supporting members and in others the lower box is so supported and the upper box is carried on saddles resting on these members. The superheater is held in its vertical position by tube clamps attached to the superheater and to boiler tubes.

LOCATION—The superheater, in Rust boilers, may be placed in one of two positions, both of which are clearly shown in the illustrations. When the degree of superheat required is not in excess of 75 degrees, the superheater is placed at the top of the second pass between the vertical baffle and the rear bank of tubes. When a greater degree of superheat than this is required the superheater is placed toward the bottom of the first pass between the front bank of tubes and the vertical baffle.

When placed in the second position, the superheater members are protected from the direct impinging of the gases of combustion by baffles, the method of supporting which may be readily seen from the illustrations. The construction of this baffle and support is such as to allow any accumulation of dust when blown from the superheater or boiler tubes to fall to the cleaning pit under the front mud drum.



BABCOCK & WILCOX SUPERHEATER IN THE SECOND PASS OF A RUST BOILER

ACCESSIBILITY—As with superheaters installed with other boilers of The Babcock & Wilcox Company's manufacture, all parts are readily accessible for cleaning, inspection and repair.

YOUNGSTOWN SHEET AND TUBE CO., YOUNGSTOWN, OHIO. BABCOCK & WILCOX SUPERHEATERS INSTALLED WITH 4000 HORSE POWER OF RUST BOILERS

BABCOCK & WILCOX SUPERHEATERS IN SERVICE

As has been stated, The Babcock & Wilcox Co. began building superheaters in 1898. Since that time they have installed Babcock & Wilcox superheaters in boilers of their manufacture aggregating over 1,650,000 horse power. These installations are in boilers supplying steam in plants representing practically every industry in which steam is used, and their successful performance is evidenced by the very large number of repeat orders.

In the consideration of the purchase of a superheater, an important factor is the responsibility of the manufacturer. That engineers as a whole realize the obvious advantage of having a single manufacturer responsible for the boiler and the superheater, rather than having such responsibility divided between two manufacturers, is shown by the fact that of all the boilers of The Babcock & Wilcox Company's manufacture which are equipped with superheaters, over 85 per cent are equipped with Babcock & Wilcox superheaters.

There follows a partial list of the users of Babcock & Wilcox superheaters and a classification of installations by industries, the horse power of boilers in which superheaters are installed being given in each instance.

Amalgamated Phosphate Company, Chicora, Fla.	4000
American Agricultural Chemical Company, Detroit, Mich.	1200
Anaconda Copper Mining Company, Tooele, Utah	3000
Armour & Company, Chicago, Ill.	2300
Bethlehem Steel Company, South Bethlehem, Pa.	6700
Boston Consolidated Gas Company, Everett, Mass.	2100
Boston Elevated Street Railway Company, Boston, Mass.	18,800
Brighton Mills, Passaic, N. J.	700
Cambria Steel Company, Johnstown, Pa.	26,700
Capital Traction Company, Washington, D. C.	9300
Carnegie Natural Gas Company, Underwood, W. Va.	1600
Central Coal and Coke Company, Rock Springs, Wyo.	900
Cincinnati Traction Company, Cincinnati, Ohio	7800
City of Cleveland Water Works, Cleveland, Ohio	2300
Colgate & Company, Jersey City, N. J.	2600
Commonwealth Electric Company, Chicago, Ill.	101,600
Delaware, Lackawanna & Western Railroad	8700
Delaware & Hudson Company	6000
Detroit Edison Company, Detroit, Mich.	29,500
Duquesne Light Company, Pittsburgh, Pa.	37,100
Edison Electric Illuminating Company of Boston, Mass.	29,500
Firestone Tire and Rubber Company, Akron, Ohio	5600
Flatbush Gas Company, Brooklyn, N. Y.	1900
Ford Plate Glass Company, Rossford, Ohio	4000
Georgia Railway, Light and Power Company, Atlanta, Ga.	6200
Gera Mills, Passaic, N. J.	750

FIRESTONE TIRE AND RUBBER CO., AKRON, OHIO. OPERATING 9300 HORSE POWER OF STIRLING BOILERS, EQUIPPED WITH BABCOCK & WILCOX SUPERHEATERS

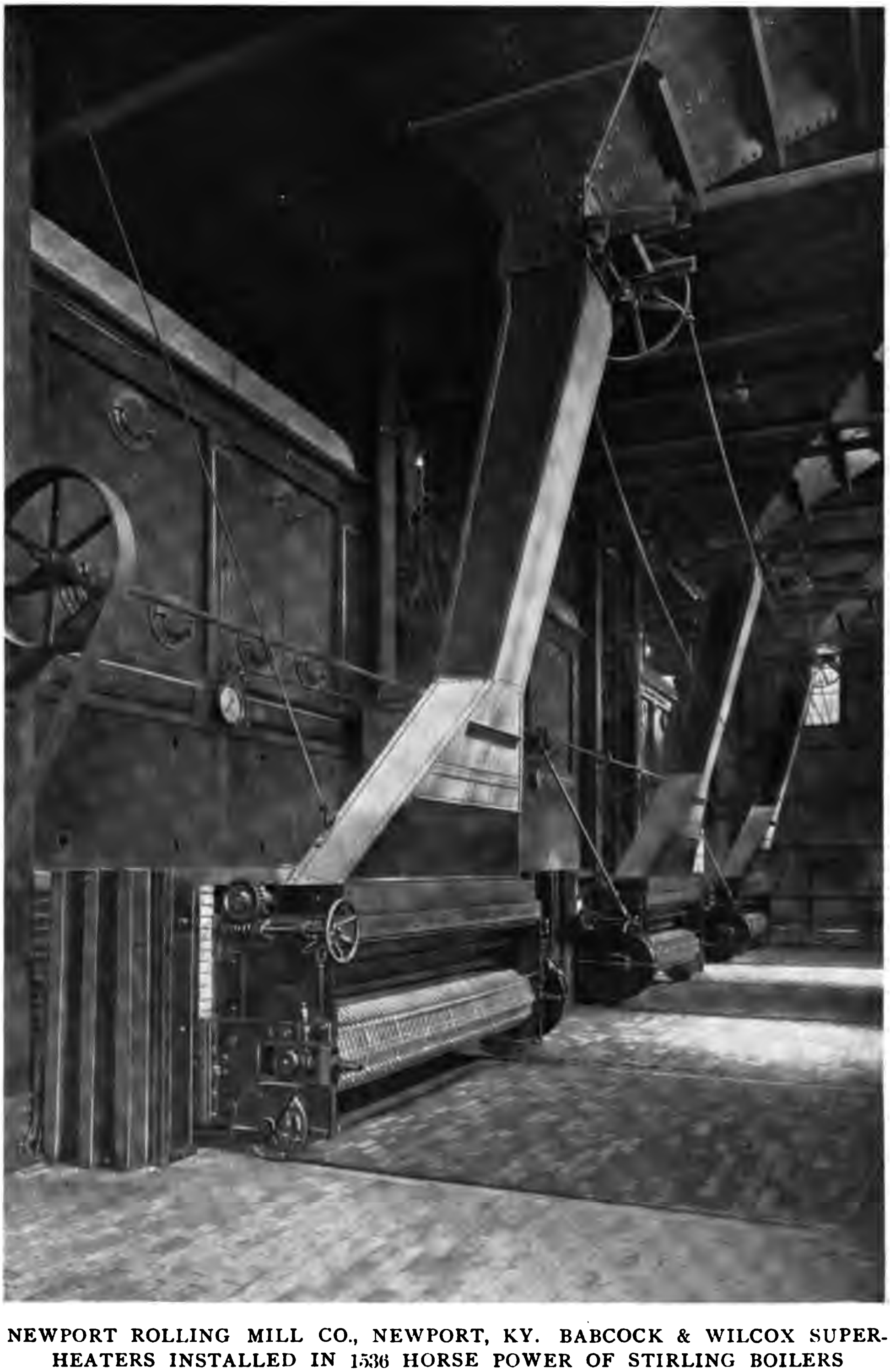
Hoster Brewing Company, Columbus, Ohio	1800
Idaho Sugar Company, Idaho Falls, Idaho	2500
Indiana Steel Company, Gary, Ind.	13,600
Interboro Rapid Transit Company, New York, N. Y.	29,400
International Harvester Company, Springfield, Ohio	1800
International Steam Pump Company, Harrison, N. J.	1800
Iriquois Iron Company, South Chicago, Ill.	6500
Lake Shore & Michigan Southern Railroad	2700
Lang Paper Company, Philadelphia, Pa.	2200
Lawrence Gas Company, Lawrence, Mass.	4900
Massachusetts Cotton Mills, Lowell Mass.	4100
Metropolitan Street Railway Company, Kansas City, Mo.	20,800
Minnesota Steel Company, New Duluth, Minn.	4600
Moron Sugar Company, Moron, Cuba	4100
New York Central & Hudson River Railroad	20,000
New York Edison Company, New York, N. Y.	117,100
New York, New Haven & Hartford Railroad	7300
Northern Ohio Traction Company	10,200
Pacific Light & Power Company, Cal.	21,700
Pennsylvania Railroad	31,800
Philadelphia Electric Company, Philadelphia, Pa.	45,300
Pittsburgh Crucible Steel Company, Midland, Pa.	8500
Potomac Electric Power Company, Washington, D. C.	15,000
Public Service Corporation of New Jersey	19,800
Public Service Company of Northern Illinois	15,000
Republic Iron & Steel Company, Youngstown, Ohio	5600
Savannah Lumber Company, Savannah, Ga.	1500
Schlitz Brewing Company, Milwaukee, Wis.	4700
Singer Manufacturing Company	8800
Solvay Process Company, Syracuse, N. Y.	11,300
Southern California Edison Company	13,000
Twin City Rapid Transit Company, Minneapolis, Minn.	15,400
United States Government Naval Vessels	141,900
Virginia Power Company, Cabin Creek, W. Va.	7000
White Mountain Paper Company, Portsmouth, N. H.	7200

GEORGIA RAILWAY & POWER CO., ATLANTA, GA. BUTLER STREET STATION
BABCOCK & WILCOX SUPERHEATERS INSTALLED IN 8400 HORSE
POWER OF BABCOCK & WILCOX BOILERS

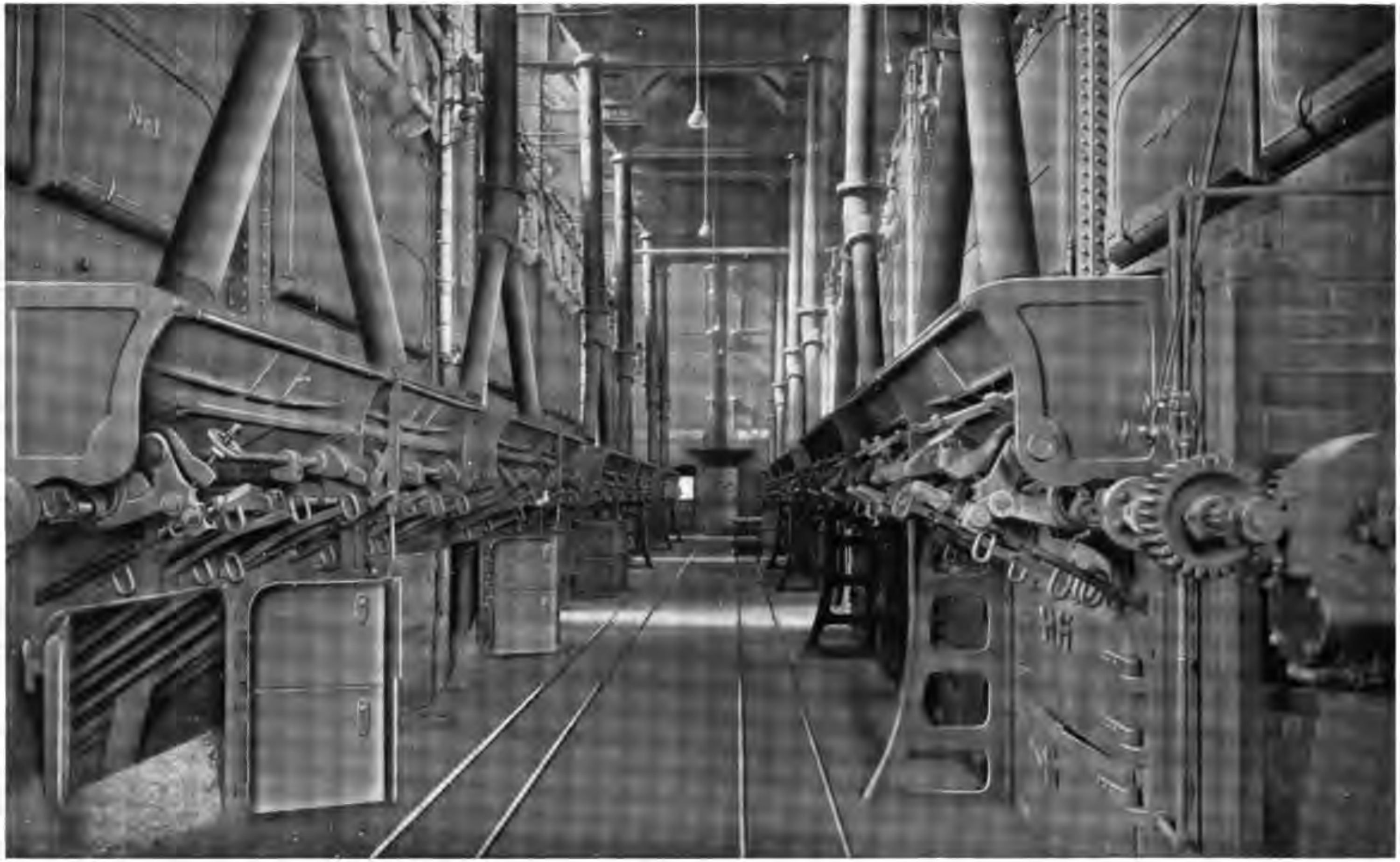
INDUSTRIAL CLASSIFICATION OF BABCOCK & WILCOX SUPERHEATER INSTALLATIONS

Agricultural Machinery	4250
Breweries and Distilleries	9150
Cement, Brick, etc.	7850
Central Stations—Electric Railways, Light and Power	1,047,100
Chemicals	18,100
Collieries	11,500
Confectioners and Bakers	2900
Copper Smelters	8200
Electrical Supplies	7500
Foundries	1300
Gas Works	21,000
Glass	5700
Hotels, Office Buildings, etc.	15,900
Iron and Steel	79,800
Locomotive Builders, Boiler Makers, Engine Builders	12,000
Lumber and Wood Working Plants	2800
Machinery and Tools	8550
Merchant Marine	29,000
Metal Working	21,450
Mining (Other than Coal)	11,500
Miscellaneous (Unclassified)	8400
Oils and Paint	2700
Packers and Canners	2200
Paper Mills	12,300
Railway Equipment	4000
Rubber Manufacturing	4100
Salt	3000
Schools and Colleges	3450
Sewing Machines	7200
Ship Builders	2100
Soap and Perfumes	2900
Steam Railroads	85,300
Sugar Plantations	8300
Sugar Refineries	9000
Textile Mills	13,300
U. S. Government Marine	141,900
Water Works and Pumping Stations	12,000

CAMBRIA STEEL CO., JOHNSTOWN, PA. 4880 HORSE POWER OF BABCOCK & WILCOX BOILERS, EQUIPPED WITH BABCOCK & WILCOX SUPERHEATERS. THIS COMPANY HAS BABCOCK & WILCOX SUPERHEATERS INSTALLED IN 26,700 HORSE POWER OF BABCOCK & WILCOX BOILERS

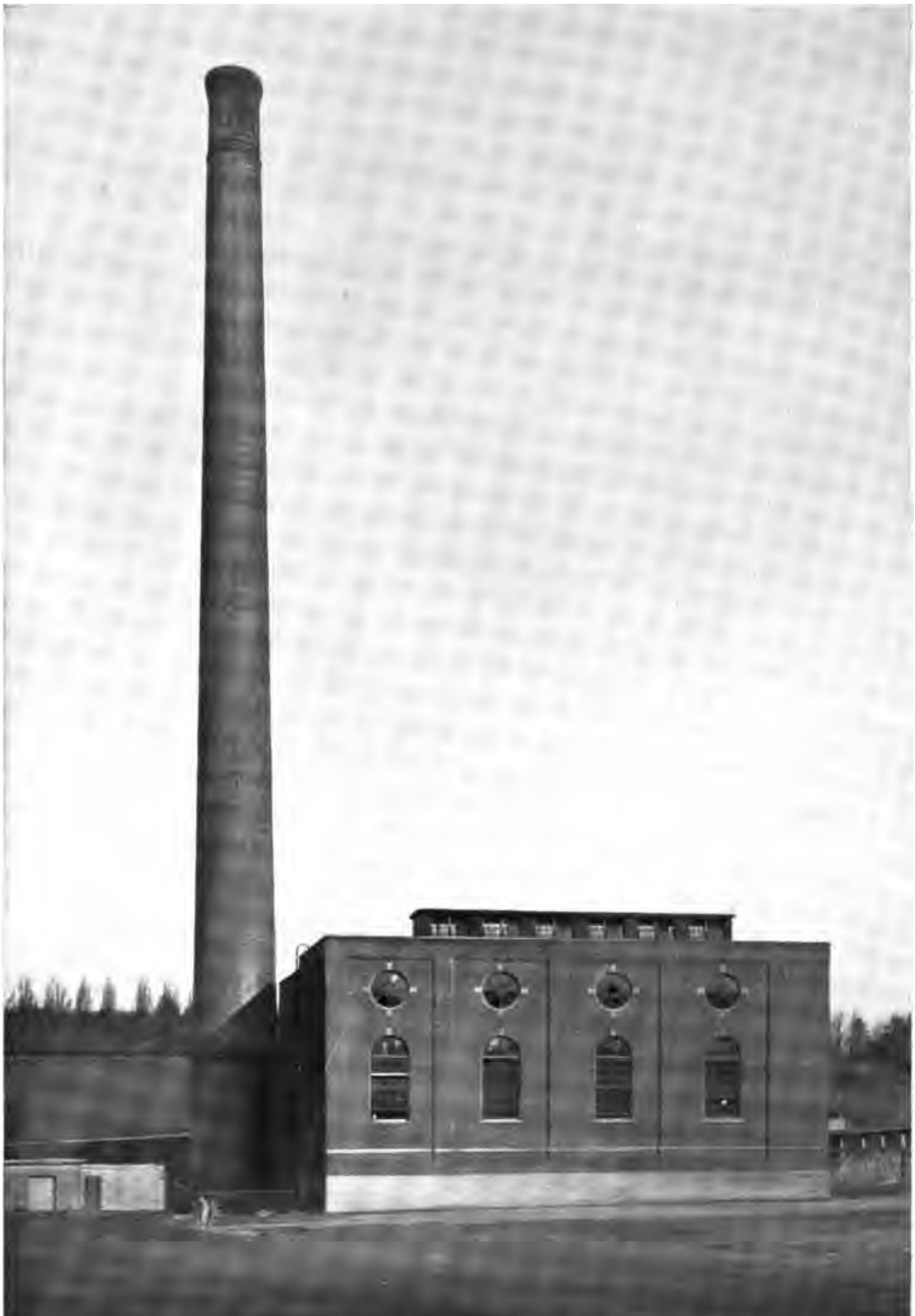


NEWPORT ROLLING MILL CO., NEWPORT, KY. BABCOCK & WILCOX SUPER-HEATERS INSTALLED IN 1536 HORSE POWER OF STIRLING BOILERS

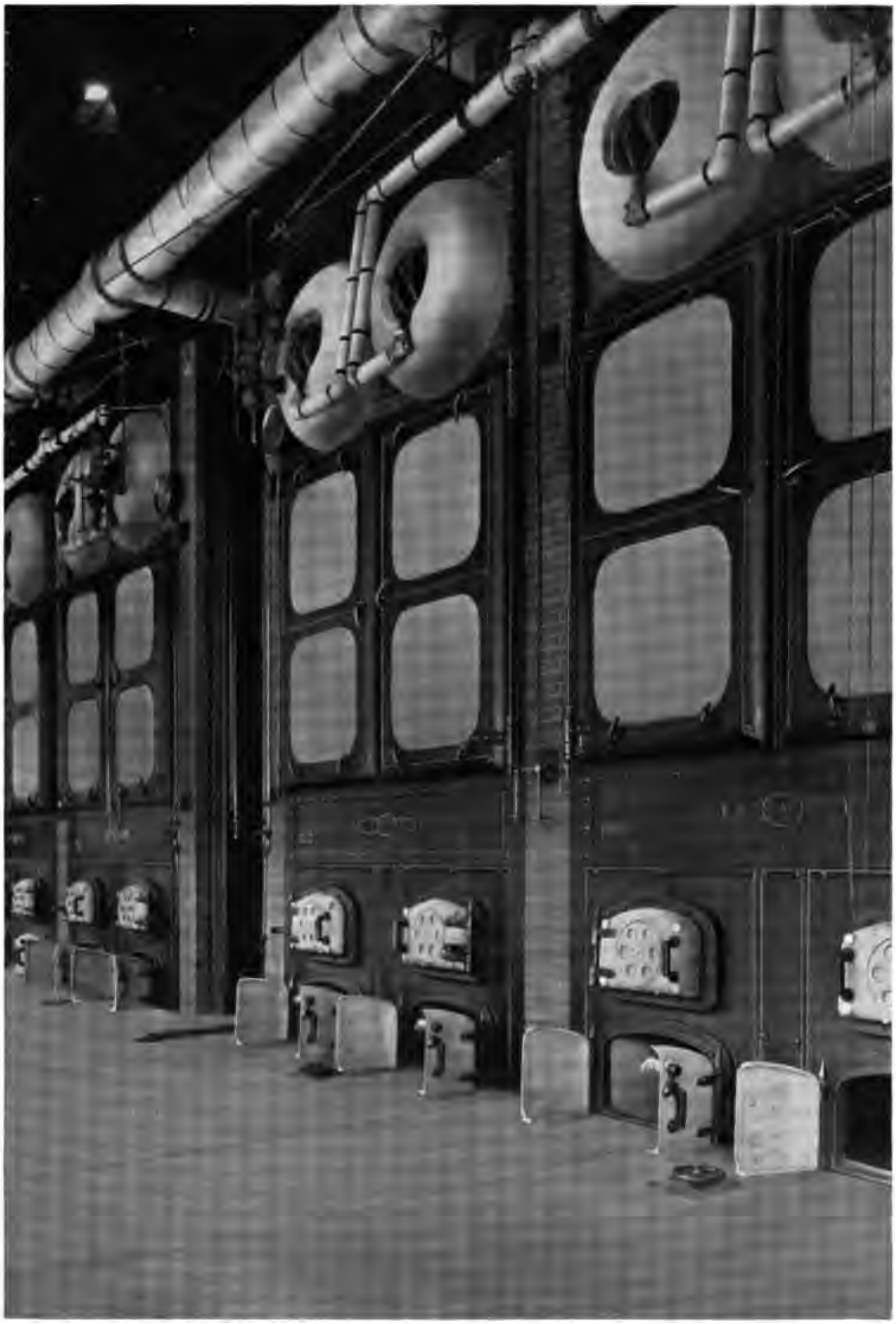


CAPITAL TRACTION CO., WASHINGTON, D. C., OPERATING 7200 HORSE POWER OF BABCOCK & WILCOX BOILERS, EQUIPPED WITH BABCOCK & WILCOX SUPERHEATERS

BOSTON ELEVATED RY. CO., BOSTON, MASS., SOUTH BOSTON STATION. BABCOCK & WILCOX SUPERHEATERS INSTALLED IN 9600 HORSE POWER OF BABCOCK & WILCOX BOILERS. THIS COMPANY HAS BABCOCK & WILCOX SUPERHEATERS INSTALLED IN 18,800 HORSE-POWER OF BABCOCK & WILCOX BOILERS IN ITS VARIOUS STATIONS

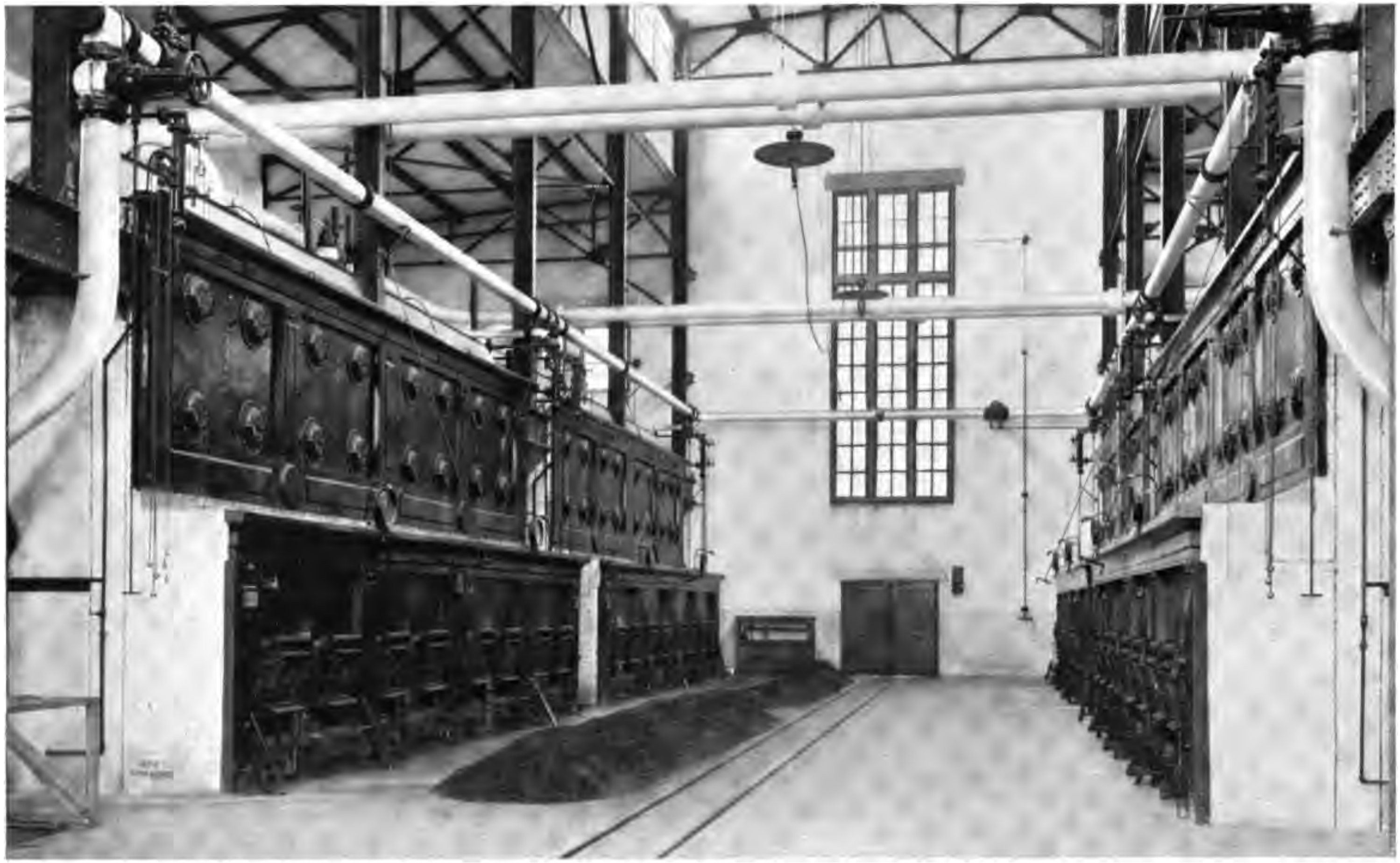


ERIE COUNTY ELECTRIC CO., ERIE, PA. OPERATING 3080 HORSE POWER OF BABCOCK & WILCOX BOILERS, EQUIPPED WITH BABCOCK & WILCOX SUPERHEATERS



CARNEGIE NATURAL GAS CO., UNDERWOOD, W. VA. BABCOCK & WILCOX SUPERHEATERS INSTALLED IN 1600 HORSE POWER OF BABCOCK & WILCOX BOILERS

TWIN CITY RAPID TRANSIT CO., MINNEAPOLIS, MINN. BABCOCK & WILCOX SUPERHEATERS INSTALLED IN 15,400 HORSE POWER OF BABCOCK & WILCOX BOILERS



DELAWARE & HUDSON CO., MECHANICSVILLE, N. Y., PLANT. BABCOCK & WILCOX SUPERHEATERS INSTALLED IN 6800 HORSE POWER OF STIRLING BOILERS

WESTINGHOUSE ELECTRIC & MANUFACTURING CO., EAST PITTSBURGH, PA. BABCOCK & WILCOX SUPERHEATERS INSTALLED IN 2400 HORSE POWER OF BABCOCK & WILCOX CROSS DRUM BOILERS

SOUTH PITTSBURGH, PA., WATER CO. BABCOCK & WILCOX SUPERHEATERS INSTALLED IN 1200 HORSE POWER OF BABCOCK & WILCOX BOILERS

COSMOPOLITAN ELECTRIC CO., CHICAGO, ILL. 4000 HORSE POWER OF BABCOCK & WILCOX BOILERS, EQUIPPED WITH BABCOCK & WILCOX SUPERHEATERS